MOTORCYCLE ACCIDENT CAUSE FACTORS AND IDENTIFICATION OF COUNTERMEASURES
VOLUME I: TECHNICAL REPORT

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16. Abstract

This report presents the data and findings from the on-scene, in-depth investigations of 900 motorcycle accidents and the analysis of 3600 traffic accident reports of motorcycle accidents in the same study area. Comprehensive data were collected and synthesized for these accidents to cover all details of environmental, vehicle and human factors.
In addition, exposure data were collected and analyzed at 505 accident sites at the same time-of-day, same day-of-week, with same environmental conditions. These exposure data define the population at risk so that comparison with accident data will reveal the factors which are over-represented in the accident population.

The analysis and review of these data identify cause factors of motorcycle accidents, relates the effectiveness of safety equipment and protective devices, and identifies countermeasures for accident and injury prevention.

Volume I is the Technical Report containing the most significant data, data analysis, findings, conclusions and recommended countermeasures.

Volume II is the Appendix with terminology, field data forms, and supplemental data and analysis.

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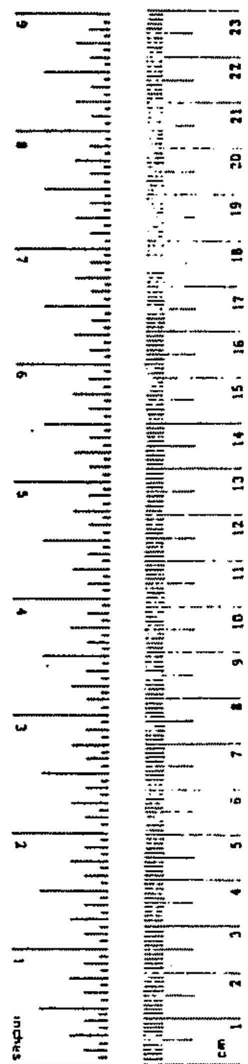
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

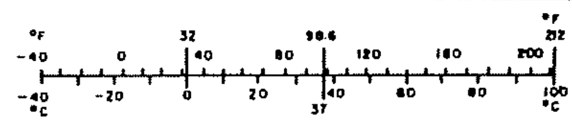
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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H. H. Hurt, Jr., J. V. Ouellet, and D. R. Thom

Objectives. Three specific areas were set as objectives in this research: (1) The causes of motorcycle accidents and injuries need to be determined so that all contributions of the motorcycle rider, car driver, roadway features, and motorcycle design are defined, (2) The effectiveness of safety helmets and other protective equipment must be determined because the motorcycle rider has no crash protection unless it is being worn on the body, and (3) Countermeasures must be determined which will prevent motorcycle accidents and reduce injuries.

Methodology. This research was conducted in Los Angeles, California, from July, 1975 until September, 1980 at the Traffic Safety Center of the University of Southern California. A specialized team was formed with engineers, psychologists, medical doctors-pathologists and motorcycle technicians. All members of the research team were required to have motorcycle riding experience so that they could appreciate and understand all hazards peculiar to the motorcycle and its accident problems. This research team underwent six months of special training to achieve a high capability in reconstructing motorcycle accidents, examining safety helmets, evaluating injuries interviewing witnesses, etc. In addition, cooperation was obtained from law enforcement agencies, fire department rescue ambulance services, hospitals and the coroner-medical examiner, so that the research team could have acces to accident scenes, interview victims and witnesses and collect injury information.

During 1976 and 1977, the motorcycle accident research team conducted on-scene, in-depth investigations of more than 900 motorcycle accidents by going to the scene of the accident at all times of the day and all days of the week. Each accident was completely reconstructed and approximately a thousand data elements were determined for each accident. Also, 3600 police traffic accident reports were collected in the same area, at the same time, for comparison with the 900 on-scene, in-depth accident cases. During 1978 and 1979, these accident cases were analyzed and exposure data collected at 505 of the 900 reference accident sites. The research teams returned to the accident sites at the same time of day, same day of week and same environemental conditions then interviewed 2310 motorcycle riders and examined their motorcycles. Information was collected about training, experience, education, helmet use, alcohol and drug use, etc., for all these motorcycle riders who were at the same place at the same time of day but not involved in an accident.

The accident data from the 900 on-scene, in-depth cases were analyzed to determine accident and injury causes. Then the exposure data were compared with accident data to determine those factors which were outstanding. For example, only 30% of the

(Continue on additional pages)

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motorcycles in the accident data had the headlamp on in daylight but 60% of the motorcycles in the exposure data had the headlamp on in daylight. Such comparison identifies the use of the headlamp on in daylight as a powerful and effective way of reducing accident involvement, by making the motorcycle more conspicuous in traffic.

Motorcycle accidents that occur in Los Angeles are essentially the same as motorcycle accidents that occur in other locations in the United States. The most frequent use of a motorcycle is in favorable weather because there is no protection for the motorcycle rider in bad weather and the motorcycle lacks stability on slippery roadways. Most motorcycle accidents occur in this favorable weather simply because of the more frequent use, and human error is the dominant feature in those accidents. Hence, the factors identified in this research should be common to motorcycle accidents in other regions. The only difference is that the favorable weather of the study area allowed the study of a very large number of motorcycle accidents.

Research Findings. The most common motorcycle accident involves another vehicle causing the collision by violating the right-of-way of the motorcycle at an intersection, usually by turning left in front of the oncoming motorcycle because the car driver did not see the motorcycle. The motorcycle rider involved in the accident is usually inconspicuous in traffic, inexperienced, untrained, unlicensed, unprotected and uninsured and does a poor job of avoiding the collision.

The data of this accident research provide the following principal findings:
(1) Accident and Injury Causes-The automobile driver fails to detect the inconspicuous motorcycle in traffic. This is due to lack of motorcycle and rider concpicuity and lack of caution and awareness of the automobile driver. The lack of skill and traffic strategy increases the motorcycle rider's involvement in collisions. Injury severity increases with collision speed, and the lack of head protection accounts for the most severe but preventable injuries.
(2) Protective Equipment-The only significant protective equipment is the qualified safety helmet, and it is capable of a spectacular reduction of head injury severity and frequency. FMVSS 218 provides a highly qualified safety helmet for use by motorcycle riders. This research shows NO reasons for a motorcycle rider to be without a safety helmet; qualified helmets do not limit vision or hearing in traffic or cause injury.
(3) Countermeasures-The basic Motorcycle Rider Course of the Motorcycle Safety Foundation is effective in training motorcycle riders; those trained riders are both less involved and less injured in motorcycle accidents. This course-or its equivalent-should be made a prerequisite, or at least corequisite, of motorcycle use and should be applied in driver improvement for those motorcycle riders who have received traffic citations or who have been involved in accidents. Licensing of motorcycle riders should be improved with special motorcycle licenses and improved testing such as has been developed by NHTSA-Traffic Safety Programs. Law enforcement should act to enforce license requiremnets, identify alcohol-involved motorcycle riders, remove dirt bikes from traffic, and effectivel cite and file against culpable accident-involved automobile drivers as well as motorcycle riders. Most motorcycles in accidents are inconspicuous, and the use of headlamps on in daylight and high visibility jackets definitely reduces accident involvement. The use of a qualified safety helmet reduces head injuries significantly and the accompanying eye protection attached to the helmet preserves vision and reduces accident involvement.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

1.0 SUMMARY

1.1 Objectives

Motorcycle accidents are a very special and severe problem. The fatalities due to motorcycle accidents are approaching five thousand per year, and have the prospect of further increase unless effective countermeasures are instituted. At present time motorcycle accidents account for approximately ten percent of the total traffic accident fatalities, but the motorcycle is only one to two percent of the vehicle population on the street in traffic.

The objectives of this research were to conduct a detailed investigation and analysis of a large number of motorcycle accidents with a highly specialized multidisciplinary research team. In this way, complete engineering and medical information could be collected and all of the accident events could be reconstructed to determine accident and injury causes. This scientific, multidisciplinary approach could provide much more exact and complete information than was available from police traffic accident reports.

Three specific areas were set as objectives in this research:

1. The causes of motorcycle accidents and injuries need to be determined accurately so that all contributions of the motorcycle rider, car driver, roadway features and motorcycle design are defined.

2. The effectiveness of safety helmets, and other protective equipment, must be determined because the motorcycle rider has no crash protection unless it is being worn on the body.

3. Countermeasures must be determined which will prevent motorcycle accidents and reduce injuries. Most accidents are preventable, and motorcycle accidents are unique and different but preventable if the causes and cures are known. The purpose of this research was to determine exactly those causes and cures.

1.2 Methodology

This research was conducted in Los Angeles, California from July, 1975 until September, 1980, at the Traffic Safety Center of the University of Southern California. A specialized research team was formed with engineers, psychologists, medical doctors and data processing specialists. All members of this research team were required to have motorcycle riding experience so that they could appreciate and understand all hazards peculiar to the motorcycle and its accident problems. This research team underwent six months of special training to achieve a high capability in reconstructing motorcycle accidents, examining accident helmets, evaluating injuries, interviewing witnesses, etc. In addition, cooperation was obtained from the law enforcement agencies, fire department rescue ambulance services, hospitals and the medical examiner-coroner, so that the research team could have access to accident scenes, interview victims and witnesses, and collect injury information.

During 1976 and 1977, the motorcycle accident research team conducted on-scene, in-depth investigations of more than 900 motorcycle accidents by going to the accident scene at all times of the day and all days of the week. Each accident was completely reconstructed and approximately a thousand data elements were determined for each accident. Also, 3600 police traffic accident reports were collected in the same area at the same time for comparison with the 900 on-scene, in-depth accident investigations.

During 1978 and 1979, these accident cases were analyzed and exposure data were collected at 505 of the 900 accident sites. The research teams returned to the accident sites at the same time of day, same day of the week and same weather conditions, and interviewed 2310 motorcycle riders and examined their motorcycles. Information was collected about training, experience, education, helmet use, alcohol and drug use, etc. for all of these motorcycle riders who were at the same place at the same time of day but not involved in an accident.

The accident data from the 900 on-scene, in-depth cases were analyzed to determine accident and injury causes. Then the exposure data was compared with the accident data to determine what factors were outstanding. For example, only 30% of the motorcycles in the accident data had the headlamp on in daylight, but 60% of the motorcycles in the exposure data had the headlamp on in daylight. This comparison identifies the use of the motorcycle headlamp on in daylight as a powerful and effective way of reducing accident involvement, by making the motorcycle more conspicuous in traffic.

Motorcycle accidents that occur in Los Angeles are essentially the same as motorcycle accidents occurring in other locations in the United States. The most frequent use of a motorcycle is in favorable weather because there is no protection for the motorcycle rider in bad weather and the motorcycle lacks stability on slippery roadways. Also, most motorcycle accidents occur in favorable weather simply because of the more frequent use, and human error predominates in those accidents. The motorcycle accidents studied in Los Angeles are essentially the same as motorcycle accidents occurring in other locations in the United States; the Los Angeles area simply had MORE motorcycle accidents available to investigate and study.

1.3 Research Findings

The most common motorcycle accident involves another vehicle causing the collision by violating the right-of-way of the motorcycle at an intersection, usually by turning left in front of the oncoming motorcycle because the car driver did not see the motorcycle. The motorcycle rider involved in the accident is usually inconspicuous in traffic, inexperienced, untrained, unlicensed, unprotected and does a poor job of avoiding the collision.

The data of this accident research provide the following principal findings:

1. Accident and Injury Causes. The automobile driver fails to detect the inconspicuous motorcycle in traffic. This is due to the lack of motorcycle conspicuity and lack of caution and awareness of the automobile driver.

The lack of skill and traffic strategy increases the motorcycle rider's involvement in collisions. Injury severity increases with collision speed, but the motorcycle rider's lack of head protection accounts for the most severe but preventable injuries. Also, motorcycle rider lack of collision avoidance skills increases injury severity.

2. Protective Equipment. The only significant protective equipment is the qualified safety helmet, and it is capable of a spectacular reduction of head injury frequency and severity. The Federal Motor Vehicle Safety Standard 218 provides a highly qualified safety helmet for use by motorcycle riders. This research shows NO reasons for a motorcycle rider to be without a safety helmet; qualified helmets do not limit vision or hearing in traffic or cause injury.

3. Countermeasures. The basic Motorcycle Rider Course of the Motorcycle Safety Foundation is effective in training motorcycle riders and those trained riders are both less involved and less injured in motorcycle accidents. This course--or its equivalent--should be made a prerequisite, or at least a corequisite, of motorcycle use and should be applied in driver improvement for those motorcycle riders who have received traffic citations. Licensing of motorcycle riders must be improved with special motorcycle licenses and improved testing such as has been developed by NHTSA-Traffic Safety Programs. Law enforcement should act to enforce license requirements, identify alcohol-involved motorcycle riders, remove dirt bikes from traffic, and effectively cite and file against culpable accident-involved automobile drivers as well as motorcycle riders.

Most motorcycles in accidents are inconspicuous, and the use of the headlamp on in daylight and high visibility jackets definitely reduces accident involvement. The use of a qualified safety helmet reduces head injuries significantly and the accompanying eye protection attached to the helmet preserves vision and reduces accident involvement.

All motorcycle riders need training, licensing, citation-related driver improvement, headlamps on at all times, bright upper torso garments, and head and eye protection to reduce accident involvement and injury frequency and severity.

2.0 INTRODUCTION

2.1 Historical Overview

The use of the motorcycle in traffic has increased greatly in recent time. During the last ten years, motorcycle registrations have more than doubled and, unfortunately, the number of motorcycle accidents and injuries has increased by approximately the same factor. The most recent statistics show that the number of fatalities attributed to motorcycle traffic accidents is approaching five thousand per year. At present time, motorcycle accidents contribute nearly 10% of the traffic accident fatalities while motorcycles are only one or two percent of the vehicles in traffic. In this way, the motorcycle appears to be the most dangerous form of motor vehicle transport.

This problem has not escaped notice, and much research has defined the obvious hazard and revealed many of the critical factors in motorcycle accidents. Elementary considerations clearly established the prospects for injury of the motorcycle rider involved in collision with another motor vehicle, simply because of the lack of a protective envelope available within the conventional automobile. Also, similar fundamental considerations established the beneficial effects of the use of the contemporary motorcycle safety helmet in preventing and reducing the deadly injuries to the vulnerable head. In addition, the lack of conspicuity of the motorcycle in traffic was identified as a special problem occurring frequently in accidents, and effectively treated by the use of the headlamp during daylight and the wearing of high visiblity clothing.

A critical contribution to the state of knowledge about motorcycle safety was the Second International Congress on Automotive Safety, in which the conference theme was Motorcycle and Recreational Vehicle Safety. This conference was sponsored by the National Motor Vehicle Safety Advisory Council of the U.S. Department of Transportation and the Society of Automotive Engineers. The literature generated by this activity represented a great increment of progress in motorcycle safety, and provided a true foundation for further research.

In spite of the critical accident factors being identified by past research and collected scientific opinions, there was a developing demand for accident data to expose the special details of motorcycle accident problems, as well as to substantiate those collected scientific opinions and past research. There were important but unanswered questions about motorcycle rider culpability, accident injury mechanisms, safety helmet effectiveness and the possibility of helmet-induced injuries, collision avoidance performance of the motorcycle rider, aggressive acts toward motorcycle riders by the drivers of automobiles, and the factors affecting the conspicuity of motorcycles.

It became apparent that the most serious questions about motorcycle accidents could not be answered by the research based upon police traffic accident reports. First, the police traffic accident reports could not be used to extend and synthesize specialized information on accident and injury causation, and second, the reconstruction of motorcycle accidents required knowledge and skills far beyond the activity typical of a police traffic accident report.

The collision dynamics and rider kinematics of motorcycle accidents were defined (Bothwell, 1973), the peculiarities of motorcycle accident investigation were described (Hurt, 1973) the limits of police traffic accident applications were defined (Reiss, Berger and Valette, 1974), and the first motorcycle multidisciplinary accident research activity demonstrated the depth of data available (Newman, 1974).

With this foundation, the requirement for extensive accident data was established, the methodology for data collection and synthesis was developed, and the applications to countermeasures were needed urgently.

2.2 Objectives of the Research

There were three basic objectives of the research. These are listed as follows:

1. To determine the causal factors of motorcycle accidents and distinguish the human, vehicular and environmental factors involved

2. To evaluate safety equipment, clothing and rider protective devices, and the motorcycle features which contribute to the serious and fatal injuries to the rider and passenger

3. To identify and define countermeasures that are conclusive, can be implemented, and which would reduce the rate and severity of motorcycle accidents

In order to support these objectives, it was necessary to complete the following investigations:

On-scene, In-depth Investigations

On-scene, in-depth investigations were conducted on at least 900 motorcycle accidents in the study area. These multidisciplinary investigations were limited to focus upon the motorcycle rather than the other vehicle involved in the collision, and all components of precrash, crash and post-crash environmental, vehicle and human factors were examined in detail. Both single and multiple vehicle accidents were considered, as were both rural and urban accidents. Also, special effort was directed to the investigation of at least two-thirds of the accidents as soon as possible after the accident event, before the vehicles had been moved from the scene so that perishable evidence was recorded accurately. Motor Vehicle Safety Standards and Highway Safety Program Standards which related directly to the motorcycle accident were evaluated for compliance and effectiveness.

The multidisciplinary accident research team had objectives of accurate collection and synthesis of data for these on-scene, in-depth investigations and the team personnel included a Motorcycle Specialist, Highway Safety Engineer, Interviewer/Psychologist, Medical Doctor/Pathologist and various specialists and consultants in the areas of helmet technology, accident reconstruction, head and neck injury, and data analysis. In addition, all accident investigation team members were required to have extensive experience riding street motorcycles.

Analysis of Police Traffic Accident Reports

Examination and analysis was conducted on at least 3600 police traffic accident reports of motorcycle accidents which occurred in the same study area in the same period of time as the 900 on-scene, in-depth accident investigations. These traffic accident reports were collected from the cooperating law enforcement agencies and analyzed and compared with the results from the 900 on-scene, in-depth accident cases. Of course, most of the 900 on-scene, in-depth accident cases were included within the set of the 3600 police traffic accident reports. However, there were some exceptions since a number of the on-scene, in-depth accident investigations did not have a corresponding traffic accident report because of lack of injury, lack of damage, lack of reporting, or lack of law enforcement response because of other priorities. Thus, the 900 on-scene, in-depth cases do not represent a complete subset of the 3600 police traffic accident reports.

Comparison of Police and On-scene, In-depth Accident Reports

The investigation and analysis of the two sets of accident data included at least the following variables:

Type of collision	Helmet use
Age	Injury severity
Sex	Weather conditions
Time	Road surface conditions
Type of motorcycle	Accident location
Roadway alignment	

Helmet Analysis, Injury Analysis

The accident-involved safety helmets were examined in the greatest detail to determine protection performance. An original objective was to sample the accident population so that about 50% of the 900 on-scene, in-depth cases would include helmeted motorcycle riders, but this objective had to be modified simply because of the actual underrepresentation of helmeted riders in the accident data. Throughout the collection period of the accident data, it was typical that approximately 50% of the motorcycle riders in traffic were using safety helmets but only 40% of the accident-involved riders were wearing a safety helmet. Consequently, the decision was made to collect the accident data without specific requirement for helmet use and to sample the accidents on an "as is" basis to best determine the actual accident involvement of helmeted riders.

The records of medical treatment of injuries were collected and, in most cases, the injuries were observed directly at the accident scene or treatment facility. Special attention was devoted to the detection of any neck injuries and their possible association with helmet use. All of the discrete injuries were encoded using the Occupant Injury Classification, and the severity was scaled using the Abbreviated Injury Scale of the American Association for Automotive Medicine. The reconstruction of accident events defined the injury producing elements, the sequence of body contacts and the causes of injury to the motorcycle rider and passenger.

Exposure Data

Exposure data elements were collected at a minimum of 500 of the locations of the 900 on-scene, in-depth accident cases. These locations were randomly selected so that the characteristics of the study area would be represented without bias, and the population-at-risk would be accurately defined. Actually 505 locations were used to collect traffic characteristics and information on 2310 motorcycle riders at the same time-of-day, same day-of-week, and same environmental conditions as the related accidents.

The original objective was to collect such exposure data as soon as possible after the occurrence of the related accident, but unexpected delays in funding prevented the timely collection of these exposure data. Under these conditions it was possible that significant changes could occur in the population-at-risk and degrade the planned comparison of accident and exposure data. Benchmark data were collected on certain critical items such as safety helmet use and headlamp use in daylight, so that reference would be available for later comparisons.

Accident and Exposure Data Comparisons

A comprehensive analysis of the accident and exposure data was conducted and oriented toward determining the relationships between the different variables of the motorcycle, environment and motorcycle rider. As a result of these analyses, countermeasures were identified which are practical and can be applied for the prevention of motorcycle accidents and reduction of injuries.

2.3 The Study Area

Selection of the Study Area

The Southern California region contributes a large quantity of motorcycle accidents, primarily because of a substantial motorcycle population and favorable weather which encourages year-round use of motorcycles. However, not all of this large population of motorcycle accidents is easily accessible for on-scene, in-depth investigation of those accidents. This aspect of accident accessibility was the critical factor in defining the study region for this research.

Los Angeles County records approximately five thousand motorcycle accidents per year with about 140 fatal accidents among that group. Within Los Angeles County there are approximately sixty law enforcement jurisdictions or divisions, which complicates accident accessibility and greatly extends communications requirements. During the first phase of this research, these complications were too great to allow coverage of the entire Los Angeles County for accident sampling.

The study area was then reduced to the City of Los Angeles so that communications and logistics could be simplified and attention could be focused upon the requirements for accident notification and accessibility. The City of Los Angeles reports approximately two thousand five hundred motorcycle accidents per year, with forty to forty-five fatalities within that group.

In this study area of the City of Los Angeles there are only two law enforcement jurisdictions, the Los Angeles Police Department and the California Highway Patrol. Both of these agencies have demonstrated a high level of support for previous accident research activities conducted by the University of Southern California. Also, within the City of Los Angeles, all rescue ambulance services are provided by the Los Angeles Fire Department, so the dispatch of emergency medical service to the scene of any motorcycle accident is done by this single agency.

Chief John C. Gerard provided the cooperation of the Los Angeles Fire Department through the motorcycle accident notifications provided by Rescue Ambulance dispatchers; Chief Daryl F. Gates provided the cooperation of the Los Angeles Police Department through accident notifications, copies of traffic accident reports, and access to the scene of accidents; Commissioner Glenn B. Craig provided the cooperation of the California Highway Patrol in the area with accident notifications, traffic collision reports and access to the scene of accidents; Dr. Thomas T. Noguchi provided the cooperation of the Los Angeles County Medical Examiner-Coroner in the cases of fatal accidents. The cooperation of these four agencies allowed the research teams to collect accident data within the area of approximately 470 square miles of the City of Los Angeles.

Representativeness of the Study Area

The study area of the City of Los Angeles is not particulary representative of other areas of the United States in terms of climate and geography. However, the motorcycle accidents within the study area are essentially identical to motorcycle accidents in other areas of the United States. It is expected that some general characteristics of motorcycle accidents will show regional variations, but critical characteristics of various accident types will be essentially the same.

For example, consider weather as a factor in motorcycle accidents. A critical issue for consideration is that the motorcycle is NOT an all-weather vehicle and it does NOT have accident characteristics like automobiles. All past and present research as well as this present study have shown that weather simply is NOT a factor in motorcycle accidents; the weather at the scene of a motorcycle accident is clear and dry in more than 90% of the accident cases. Environmental factors contribute in a minority of accident cases, i.e., less than five percent of the accident cases. The motorcycle accidents which occur in fair weather in other parts of the United States are essentially identical to the motorcycle accidents which occur in fair weather in the selected study area. The few motorcycle accidents which occur in truly adverse weather are only a minute part of the total motorcycle accident problem. When there is snow, ice and water on the road, cars and trucks suffer from a loss of traction and are involved in accidents more frequently, but the motorcycles are stored in the garage or carport and the motorcycle rider is using some other form of transportation!

The distinguishing factor for the Los Angeles area is that the high incidence of favorable weather allows greater use of the motorcycle and this additional exposure generates more accidents, but not significantly different accidents. The major elements of accident and injury causation are well

represented by the large quantity of accident data from this study area of Los Angeles, since the greatest part of all motorcycle accidents occur under similar favorable environmental conditions.

The study area is predominantly urban and suburban, with rural land use diminishing as in similar metropolitan areas. The street motorcycle is traditionally a vehicle associated with urban rather than rural life, and the accident characteristics should be peculiar to the vehicle type rather than land use. Consequently, the accident data collected and analyzed here will show accident characteristics of helmet effectiveness, injury mechanisms, collision avoidance performance, etc., which are more appropriate to the accident configuration rather than the land use at the accident site.

California does not have laws requiring the use of motorcycle safety helmets, eye protection, headlamps on in daylight, etc. While this situation may be unfortunate from the standpoint of accident and injury prevention, the accident population offers a good sample to evaluate the effectiveness of those items as accident and injury countermeasures. California does have a requirement for a special motorcycle license which is obtained by a special written examination and separate skill test, so this factor can be evaluated for its effectiveness as an accident countermeasure.

These factors describe the study area as <u>generally</u> representative for the purposes of analyzing the special characteristics of motorcycle accidents, and the findings, conclusions and recommended countermeasures will be applicable to the greatest part of motorcycle accidents in the United States. The <u>special</u> characteristics of motorcycle accidents related from this research will be found to be <u>essentially identical</u> to those motorcycle accidents occurring in other areas.

2.4 Acknowledgements

Many people contributed in important and critical ways to the collection and analysis of these motorcycle accident data, and the progress of this research.

- Nicholas G. Tsongos is the Contract Technical Manager for this research. His guidance, support, leadership and encouragement were critical elements in this research work, and were greatly appreciated.

- William E. Scott is the Director of the National Center for Statistics and Analysis and his interest and support for high quality, scientific research is encouraging to all researchers in traffic safety.

- Lewis S. Buchanan of Traffic Safety Programs at NHTSA has given valuable advice and support for this project. His interest and concern for high quality factual research in motorcycle safety was stimulating to the research team.

- Don Mela and Henri A. Richardson of the Mathematical Analysis Division of NCSA have given valuable guidance in the directions of data analysis and this interest was greatly appreciated.

• Ivan J. Wagar, President of the Safety Helmet Council of America, has advised and counselled the research team in many important ways. His personal contributions of time and energy are so great that his help is truly without equal.

One of the most important contributions was that arrangement of SHCA membership to provide replacement helmets for the accident-involved motorcyclists. This support was crucial for obtaining the accident-involved helmets for detailed examination and analysis.

• Alan Jones, Ran Hooper, David Sandiford and Jim Young of Electrofilm donated many replacement helmets and assisted the research team in helmet analysis and accident replication.

• Dean Fisher, Frank Falley, Jim Sundahl, and Dee Tryon of Bell Helmets donated many replacement helmets and assisted the research team in helmet analysis.

• Lynda Montgomery of American Sports donated many replacement helmets.

• Pat Donnelly of Shoei donated many replacement helmets.

• Ken Miller of Florida Safety Products, Dick Lash of Abadon-NJL, and Ray M. Drake of American Safety, also donated replacement helmets.

• Daryl F. Gates is Chief of the Los Angeles City Police Department. The cooperation and assistance of LAPD officers was vital to all the research activities, and this help was given freely with obvious priority and support for scientific accident research.

• Glen B. Craig is Commissioner of the California Highway Patrol. The cooperation and assistance of CHP officers was vital to the investigation of those accidents on highways and freeways in the study area. This help was always given with clear support for scientific accident research.

• John C. Gerard is Chief Engineer of the Los Angeles City Fire Department. The cooperation of the Operations Control Division, the Rescue Ambulance Dispatchers, and the Rescue Ambulance crews was vital to accident notification and data collection procedures.

• Dr. Thomas T. Noguchi is the Chief Medical Examiner-Coroner of the County of Los Angeles. The support and assistance from this office was vital and always reflected the highest scientific capabilities and professional research interests.

• Dr. Harriet Smith McMurria was the Medical Consultant for the research team and her interest and devotion to this project was greatly appreciated.

• Jon S. McKibben was the Principal Consultant to the research team and his advice and counsel in all areas of accident reconstruction and motorcycle technology was a vital ingredient for the research, and contributed significantly to the collection of accident data.

- Carl Arrowood and Phil Sheets of Kawasaki provided much help to the research team in advising on the legal problems of accident data collection. This legal and technical advice was often used during the data collection activities.

- Dr. James A. Newman served as the Consultant to the research team in helmet technology and head and neck injury analysis, and his contributions were vital to the collection of quality data.

- Dr. G. A. Fleischer served as the Consultant to the research team in data processing and analysis and his guidance was critical to the collection and analysis of the accident data.

- Chet Hale, Dick Madsen, and Russ Daly of Honda were always available for technical assistance and information.

Also, special thanks are due to Takenori Yamamoto of Honda R & D. Yamamoto worked as a visiting scholar with the research teams in field investigations, accident reconstruction, and data analysis. This special interest in applying accident data to vehicle design reflects a true concern for safety.

- Leo Lake and Monte Hayakawa of Yamaha were always available for technical assistance and information.

- Lynn Hippleheuser was the producer of the film project on "Helmet Effectiveness," and his special talent and skill were the critical ingredients in that production.

Finally, there were hundreds of motorcycle riders who participated in this research and cooperated with the research team and gave interviews and information about themselves and their accidents. The common thought among these riders was that they wanted this information about their accident to help other motorcycle riders.

3.0 DEVELOPMENT OF THE RESEARCH

3.1 Technical Approach

A motorcycle accident is actually a very complex event, involving the interaction of many complicated human, vehicle, and environmental factors. In this way, it is no different from the more typical motor vehicle accident involving the contemporary passenger sedan. However, the motorcycle accident involves special areas of vehicle systems, vehicle dynamics, and human factors and requires special considerations for the accurate collection of accident data.

Accident investigation methodology for motor vehicles such as automobiles and trucks is developed and practiced to a high degree of refinement. The state-of-the-art is such that most cause factors can be determined by the in-depth analysis of the engineering, physiological, psychological, environmental, etc., factors. The very great majority of trucks and cars have great commonality of vehicle systems, vehicle dynamics, and human factors related to accident causation. When considered carefully, the collision speed analysis of a truck accident can employ the same methodology as is employed in the speed analysis of a passenger car accident.

The investigation of motorcycle accidents poses different and confounding problems even at present time. The mechanical systems of motorcycles are vastly different from the mechanical systems of automobiles; the stability and control of the single-track vehicle is <u>spectacularly</u> different from that of the conventional automobile; the collision dynamics of the motorcycle are far different from those of conventional automobiles, and related injury mechanisms require special study. The analysis of pre-crash speeds, skid marks, crash contact conditions, and post-crash dynamics in motorcycle accidents involves many factors <u>uncommon</u> to the analysis of automobile accidents. As a result, the methodology of motorcycle accident investigation is not well practiced and the state-of-the-art is such that most motorcycle traffic accidents receive only casual or perfunctory investigation. In turn, the entire body of previous motorcycle accident data has low credibility and safety countermeasures are difficult to verify and validate.

There are many serious questions in motorcycle accidents regarding injury mechanisms, vehicle defects, alcohol involvement, and validation of vehicle and program safety standards. The answers to these questions, and the development of effective safety countermeasures strategies, will depend in great part on the development of a successful accident investigation and analysis methodology. For these reasons, the technical approach used in this research had to employ a strategy that produced credible and valid results.

In order to produce the required quality of accident data it was necessary to staff and train the research team for the specific objectives. The prerequisite of the research team member was street motorcycle riding experience. The priority for such experience was established for all team members so that the critical perspective would be given to all areas of data collection.

Also, all members of the research team were required to develop a substantial knowledge of motorcycle mechanical systems, motorcycle accident injury mechanisms, and motorcycle vehicle dynamics. This was necessary so that a

common ground of terminology and data would be established throughout the research team. Consequently, a special training program was developed by and for team members. In addition to the members of the proposed research team, it was necessary and desirable to include personnel from outside the team from cooperating agencies and organizations, e.g., law enforcement, rescue services, coroner-medical examiner, etc. Special lectures were prepared and conducted for cooperating agencies.

The content of the staff training program was directed to the specialized areas necessary for the motorcycle accident investigation process. The approximate content of this special instruction was as follows:

Vehicle Systems. Electrical systems, ignition, lights, accessories, signals, suspensions, forks, dampers, seals, damage, maintenance, shocks, wear and degradation, swing arm structures, frame integrity. Engines and transmissions, wear and degradation, clutch and shifter, controls, cable maintenance and failure analysis, chains and sprockets, shafts and gear housings, surge and snatch. Fuel systems, slide and CV carburetors, tank integrity, crash fires, analysis of fire origin. Wheels and brakes, spoked and solid wheels, hubs, drum and disk brakes, controls, mechanical and hydraulic, failure and malfunction analysis. Tires, tubes, characteristics, street, universal, off-road, trials and knobbies, skid marks analysis, failure analysis. Motorcycle defect investigation techniques. Street, enduro, trail, MX, desert, etc., case studies.

Injury Mechanisms. Car-motorcycle collision analysis, motorcycle-stationary object collision analysis, fall analysis. Motorcycle-rider-car-object collision contact conditions. Anatomical matters, injury physiology associated with motorcycle accidents. Abrasion, impact, penetration, fracture, burns, protection technology. Head injury, concussion, fracture, fracture and depression, brain and skull injury mechanics, vulnerability areas, contre-coup injury. Safety helmet design and manufacture, relation to standards and injury protection, ANSI Z-90 SHCA, Snell, FMVSS 218; retention, impact attenuation, penetration resistance. Test qualification, relation to injury analysis, test process, wire guide and monorail test systems. Failure analysis, injury correlation.

Vehicle Dynamics. Motorcycle equilibrium conditions, steady and accelerated motion. Normal, side, and traction force requirements. Anatomy of a turn, transient and steady conditions. Acceleration and braking performance, representative motorcycles. Tire characteristics, camber and cornering stiffness. Longitudinal motions, two-stroke surge, wheelies, end-overs. Lateral-directional motions, slide-out or low side, high-side, tank-slapper, limits of cornering; lateral-directional dynamics, capsize, weave and wobble modes, pitch-weave, load effects. Applications to accident reconstruction; considerations of vehicle characteristics, defect related areas, effect of rider experience, roadway conditions, collision avoidance performance of motorcycles.

Accident Reconstruction. Case studies, collision contact conditions, injury sources, speed analysis, trajectory calculations, loss of control analysis.

Vehicle Familiarization. Operation and practice with street bikes, semi-choppers, etc., skid mark, scrapemark analysis.

Past experience at University of Southern California has shown that research and teaching activities are best related to public needs when these activities are guided by the advice of experts in the appropriate field. It is of great value to provide the research staff with the advice and counsel of experts who can provide a special level of independent consultation.

Because of the concern for developing educational and research programs in the field of motorcycle safety, a USC Advisory Committee for Motorcycle Safety was formed. This advisory committee provides expert advice and counsel for all present and future activities in motorcycle safety and guarantees that these activities best serve the public interest.

The membership of the USC Advisory Committee for Motorcycle Safety is as follows: Mr. Ivan J. Wagar, (Chairman), President of Safety Helmet Council of America, Dr. John P. Stapp, Professor of Human Factors, USC Institute of Safety and Systems Management, Dr. Gerald A. Fleischer, Professor, Industrial and Systems Engineering, USC School of Engineering, Mr. Jon S. McKibben, President, McKibben Engineering Corporation and Lecturer in Safety, USC, Mr. Chet Hale, Vice President, Technical Division, American Honda Motor Co., Inc., Dr. Irving Rehman, Professor of Anatomy, USC School of Medicine, Dr. David H. Weir, Consultant, Mr. H. H. Hurt, Jr., Professor of Safety, USC Institute of Safety and Systems Management.

The advisory committee and its individual members have served to advise the Institute of Safety and Systems Management on all activities in motorcycle safety such as motorcycle accident investigation methodology, accident cause factors, injury mechanisms, safety countermeasures development, safety education courses, and vehicle technology.

This expert counsel and guidance was given to the Motorcycle Accident Research Team throughout the research operation. The combination of the broad qualification plus specialized motorcycle experience of the proposed research team and the expert guidance of the advisory committee guaranteed that the research results would be of high quality.

3.2 Project Schedule

The major activities of this research took place in the following schedule:

July 1975 through December 1975: Staffing, Development of the data system, Establishment of field cooperative agreements, Team training and practice operations.

January 1976 through December 1977: Accident data collection, Team retraining, preliminary data quality control, Field cooperative activities, refining of notification system.

January 1978 through December 1979: Accident data case review and quality control, Data editing, Data analysis and review.

July 1976 through December 1976: Development of exposure data system.

July 1978 through March 1980: Exposure data collection, Exposure data editing, Data analysis and review.

January 1979 through December 1979: Script and production development of helmet effectiveness film, On-scene and studio filming, Film editing.

January 1980 through September 1980: Accident and exposure data compilation, Final analysis and review, Final report preparation.

Three other reports of these activities were prepared and submitted: (i) Phase I Report - January 1976, (ii) Status Report of Accident Data - January 1979, (iii) Motorcycle Safety - Helmet Effectiveness, a film presentation of Status Report findings relating to motorcycle safety helmets. DOT 9-001.

3.3 Project Personnel

The project personnel were as follows: Principal Investigator: H. H. Hurt, Jr., Research Associate: J. V. Ouellet, Motorcycle Specialist: D. R. Thom, Project Manager: S. L. Browne, Administrative Coordinator: S. J. Bakerink, Research Assistants: V. W. Owens, R. A. Pollack, W. D. Kutz, J. D. Hurt, E. D. Lougee, J. A. Bakerink, G. J. Graham, L. Slycord, L. D. Rudy, T. Y. Tamura, C. J. Dupont, C. C. Howard, T. J. Fain, L. J. McKenzie, and J. Engleman, Programmer Analysts: R. Chang, M. L. Hanson, Secretarial Staff: R. Lucero, S. DeShong, D. C. Davidson, Principal Consultant: J. S. McKibben, Medical Consultant: H. S. McMurria, M.D., Helmet Technology Consultant: J. A. Newman, Ph.D., Data Consultant: G. A. Fleischer, Ph.D.

In addition, the personnel of the Air Force Audio Visual Services Center at Norton Air Force Base produced the videotape film on Motorcycle Safety-Helmet Effectiveness. Lynn W. Hippleheuser was the producer and Bob Mack was head of the writers staff.

3.4 Data Collection Plan

Accident Data Collection

A detailed plan for sampling of accidents was prepared and submitted with the Phase I report. During the early parts of accident data collection activity it was clear that such detailed strategic plans could not be followed; the accident cases collected were limited by the availability of timely accident notifications and resources of the research project.

During the two years of accident data collection, approximately 4500 motorcycle accidents were recorded by traffic accident reports in the study area. Timely notification was received by the research team for approximately one-half of these accidents. The research team was able to respond to and initiate on-scene, in-depth investigation on 1126 of these notifications, of which 900 could be completed satisfactorily for data purposes. In other words, only 20% of the recorded accident population could be sampled for the detailed on-scene, in-depth accident data collection. In view of the basic resources of this research project, and the relatively large volume of accidents in the

study area, this 20% sampling is considered to be the upper limit attainable for such research data collection activities.

Two factors limited the acquisition of accident data for the detailed on-scene, in-depth investigation. First, more resources and more personnel could have been employed to respond to notifications but this would have increased costs. Some cases were declined when the research staff was saturated with other cases, but this was actually a rare problem, involving less than 6% of the notifications received. The second factor limiting accident acquisitions was the performance of the notification system. The principal difficulty is the priority of actions by emergency services; law enforcement control of the accident scene and medical care for the injured must take place without interference or interruption. In this way, accident research activities must operate completely at the periphery of emergency services and accept whatever communication of notification may be available without conflict. Many different approaches were tried to improve the accident notification system to increase timeliness and thoroughness of accident event detection, and the limits were constantly strained. <u>Maintenance</u> of the notification system was the dominant effort, <u>improvement</u> could not be made to increase acquisition beyond <u>20%</u>.

With the limitations of accident notification and project resources, the acquisition of accident cases for on-scene, in-depth investigation was considered to be limited simply by available accidents. In this way, the accident data is considered to be without bias and may be peculiar only to the study area.

Collection of traffic accident reports within the study area was not difficult because of the special cooperation of the Los Angeles Police Department and the offices of the California Highway Patrol. However, the collection was tedious and required much telephone communication, travel and time. The 3600 police traffic accident reports were collected, analyzed and processed without significant difficulty or delay.

<u>Exposure Data Collection</u>

The original plan for collection of exposure data had expectation of returning to the site of each of the 900 on-scene, in-depth accident investigations at the same-day-of-week and time-of-day as soon as possible after the accident. Procurement delays and reductions of funds available required alteration of this original plan in calendar time and number of data collection sites.

The changes required that the number of sites for exposure data collection be reduced to 500, and that the exposure data be collected approximately two years later. Five hundred accident cases were selected from random groups so that the monthly distribution approximated the accident distribution, e.g., 6.5% of the OSIDI cases were collected in March so 6.5% of the exposure sites were selected from the March OSIDI accident sites. Locations with significant environmental changes were omitted. In addition, selected benchmark exposure data were collected during the times of accident data collection, when the delays of detailed exposure data collection were confirmed. Specific data were collected on helmet and headlamp use.

Actually, exposure data collection was conducted for 505 locations, and data were obtained for 2310 motorcycles and riders.

4.0 RESEARCH METHODOLOGY

4.1 Liaison and Cooperative Agreements

The acquisition of all the necessary accident data is a complex task requiring extensive interaction with a large number of agencies and groups. Basically, there were five critical requirements for the acquisition of accident information:

1. The team must receive notification of an accident at the time the accident occurs, with reliable identification of motorcycle involvement.

2. Once on scene, the data collection team must gain access to accident involved parties and vehicles. Such access is the responsibility of the investigating police officer, whose full cooperation was vital.

3. Follow-up of on-scene accidents, and the encoding of data from 3600 police reports required acquisition of police reports in a consistent, reliable and timely manner.

4. Acquisition of injury data required the cooperation of emergency treatment facilities, hospitals, group and private physicians and the Coroner's office.

5. A thorough examination of the accident-involved helmet necessitated bringing the helmet to the office for disassembly and analysis. It was thus critical to find a way to persuade a rider to donate his safety helmet.

Notification

Because of the size and complexity of the radio communications systems of the City of Los Angeles Police Department (LAPD) and California Highway Patrol (CHP), and the relatively low proportion of accident notifications occurring on these frequencies was ruled out. However, the City of Los Angeles Fire Deparment (LAFD) dispatches rescue ambulances to locations throughout the entire 470 square mile study area over three different radio frequencies. Most of the accident notifications to USC were obtained by monitoring these frequencies. A formal cooperative working agreement was established with the Los Angeles Fire Department, in which notifications of motorcycle accidents were broadcast, including the location and time of the accident. Further, intensive efforts were made to contact all rescue ambulance personnel on a face-to-face basis in order to explain the research effort. These efforts resulted in an increased notification rate, as ambulance personnel often reported back previously undetermined motorcycle involvement in the accident to the dispatcher, who then notified USC.

A second source of accident notifications was established with the "complaint board" of LAPD. Communications officers receiving telephonic notification of a motorcycle accident from a citizen would first forward the information to the radio dispatcher and then call to notify the research team.

Normally, radio and telephone communications were monitored constantly by project personnel. However, when the teams were in the field, or off duty, telephone communications were recorded with automatic recording equipment; radio communications

were recorded on tape with a carrier-activated monitor. Thus, notifications that occurred while the team was not on call were recorded and then followed up if the accident met sampling requirements.

Notification of fatal accidents was usually by means of telephone communication with the Coroner's office every morning, to determine whether any acquirable accidents had occurred. A number of fatalities were acquired through the other communication channels, i.e., LAPD, LAFD and CHP.

Despite the variety of notification sources, the team was notified in time to respond to approximately one-fourth of the reported accidents occurring in the study area. Even this level of notification required conscientious attention to maintaining frequent interaction with the individuals manning radio and telephone communication sources.

On-Scene Access

The cooperative agreements with Los Angeles Police Department and California Highway Patrol provided official approval from headquarters for USC investigators to examine accident-involved vehicles and scenes. While this was still subject to the discretion of the investigating officer on scene, not a single case occurred in which the research team was denied access. In many instances, officers assisted team personnel by introducing investigators to accident-involved parties and assuring them of the research nature of the investigation, or by escorting USC personnel into hospital emergency rooms for interviews and medical information.

A critical part of the accident investigation activities was to gain access to tow yards and impound facilities where the accident-involved vehicles — usually the motorcycles — were often taken. In most cases, these were Official Police Garages (OPGs) working under contract with the police department. Establishment of the official cooperative agreements with the Los Angeles Police Department and California Highway Patrol effectively opened the OPGs to USC personnel.

Acquisition of Accident Reports

Following establishment of the cooperative agreements with the Los Angeles Police Department and the California Highway Patrol, the flow of accident reports from their initiation at the accident scene to their final record storage was studied, and key points for extracting reports from the system were identified. This allowed rapid acquisition of traffic accident reports (TARs) for follow-up of in-depth investigations. Those TARs that were not needed for accident follow-up and were not extracted early in the flow were generally allowed to proceed to record storage. The individual California Highway Patrol offices held all motorcycle accident reports for regular pick up. Los Angeles Police Department reports that were not extracted from the system initially were acquired utilizing computer identification of motorcycle-involved accidents. This assured acquisition of all reports of motorcycle accidents for tabulation in the 3600 cases.

Injury Data

Injury data was acquired from a variety of sources. In many cases, if the accident was minor and involved only superficial injuries to the rider, and the rider expressed no intention of seeing a physician, the injury information was

taken by the on-scene investigators. Whenever possible, this was followed up with a phone call some time later to determine whether additional injuries had been discovered after leaving the accident scene.

When the injured rider or passenger was transported to a hospital emergency room, every effort was made to visit the emergency room to speak to the injured rider and acquire initial injury data. This was of great value, since tell-tale abrasions and skin injuries that can help define rider kinematics are often lumped together in emergency room reports as "multiple abrasions and contusions to the body." Whenever possible, diagnostic tests such as X-rays were examined and documented by notes or photography. Riders who were treated by physicians were usually followed up by one of two resident pathologists who worked as consultants to the project. The pathology consultants contacted the treating physician, hospital personnel, or the injured riders, to verify the nature and location of the injuries.

Injury information in the fatal cases came, of course, from the Coroner's office. Completed autopsy protocols were obtained from the Coroner's office in all fatal accidents, and this was sometimes augmented by attendance of project personnel at the post-mortem.

Helmet Acquisition

In order to obtain the rider's helmet for thorough examination and evaluation after an accident, an agreement was made with the Safety Helmet Council of America (SHCA) for the member companies to donate a new helmet of equal or superior quality to the rider who would donate his "lucky" helmet to the USC Motorcycle Accident Research Project. Although many riders initially wished to keep their accident-involved helmet for display on the mantel at home, the offer of a brand new helmet in trade was crucial in their decision to donate the old helmet to research. In this way 73.4% of the helmets involved in accidents were brought to the office for thorough examination, then most were retained for further study.

The cooperation of all these public and private agencies was assured by the activities of the research teams in providing equivalent support to the cooperating agencies. For example, guest lectures were given at local high schools at the request of Los Angeles Police Department and California Highway Patrol, training sessions in skid mark analysis and speed estimation were conducted for LAPD, CHP and Los Angeles Sheriff's Office, training sessions in helmet technology were given for LAPD and CHP, seminars were conducted for Safety Helmet Council of America membership on research findings, and technical assistance was given to LAPD and CHP in accident reconstruction of special cases. These activities were presumed necessary equivalent cooperative assistance.

4.2 Team Training

The first six months of the project were used to bring all the research personnel to a high level of familiarity with all the tasks and background knowledge that would be required to insure maximum quality in the collection of accident data. The full range of topics covered has been described in greater detail in the Phase I report of this study (Hurt, 1976), and is described more briefly here.

Team Field Relations

Because of the extensive interaction between the private and public agencies involved in various aspects of motorcycle accidents, a considerable amount of time was spent orienting the team members to the official requirements of the public agencies, the nuances of the specific ways in which the agencies perform their jobs and basic "etiquette" for accomplishing research goals while causing minimum disruption of the normal work of those persons working in cooperating agencies.

Part of the basic orientation was accomplished through lecture and field work with members of an on-going automobile accident research team also working in the USC Traffic Safety Center. This included on-scene investigation of accidents, visits to tow yards, emergency rooms, etc.

Team personnel also visited the Los Angeles Police Department and the Los Angeles Fire Department communications centers to watch the specific flow of notification data and to familiarize communications personnel with the team notification requirements. Similar visits to tow yards were made to ensure future ease of access to accident-involved motorcycles and cars to familiarize team members with legal requirements of tow yards. As part of the training, team members rode along with California Highway Patrol and Los Angeles Police Department officers on routine patrol.

Accident Investigation Methodology

Of course, scientific investigation of motorcycle accidents requires a thorough familiarity with the elements of accident investigation methods — general methods as well as those peculiar to single track vehicles such as motorcycles. All the team members were trained, in both lecture and practice, in the basics of accident investigation. Some of the topics included interviewing and evaluation of witness statements, collection and analysis of environmental data, analysis of vehicle damage, injury causation, photography and photographic documentaion of evidence, collision dynamics, and the reconstruction of collision events from physical evidence.

Essentially, the training sequence progressed from lecture to demonstration to practice by the team members with critique and feedback from instruction personnel and other team members. Part of the training included an entire day at a test facility evaluating skids made under a wide variety of conditions of different motorcycles.

Vehicle Systems

The major components of the motorcycle were reviewed: tires and wheels, braking systems, electrical systems, suspension, fuel delivery and exhaust systems, drive train and so on. Special emphasis was placed on failure and defect analysis, failure modes and the evaluation of evidence that might suggest some type of vehicular defect or failure. Training also focused on the determination of fuel and ignition sources in fires and the differentiation of collision damage from problems present in the motorcycle prior to the collision.

Vehicle Dynamics

Because of the peculiar handling characteristics of single track vehicles such as motorcycles, mopeds, and bicycles (e.g., see Hurt, 1973) it was essential that team personnel have a formal understanding of motorcycle dynamics and the factors that influence those dynamics. Those were accomplished largely through lecture and review of case histories. Topics included: turning, acceleration and braking, instability modes such as slide-out, wobble, weave, high-side, and capsize, the effects of motorcycle modifications, maintenance, tires, passenger involvement, etc., as well as the detection and evaluation of evidence indicative of instability problems.

Injury Mechanics

Injury mechanics training was largely through lecture methods. To a large extent, prior biomechanics research in automobile and aviation accident investigation provided much of the background information on injury mechanisms. However, much of the application of this information to motorcycle accidents came simply through extensive experience of relating the collision dynamics to vehicle damages and rider kinematics in practice accident investigations during the latter part of the training period.

Helmet Technology

Team training included a thorough familiarization with helmet function, design and manufacture. Team research personnel visited the manufacturing and test facilities of a number of major helmet manufacturers in the Los Angeles area to learn details of helmet construction methods, consult with design and test personnel on the performance characteristics of various materials and designs and to see helmets tested in accordance with the various standards.

Data Forms

Of course, every accident is a unique combination of factors, and while there may be many points of similarity between two accidents, each still has critical differences. Obviously, one could simply write a narrative description of each case, but the usefulness of a narrative for retrieval of information and statistical analysis is very limited. The requirement that the accident information be retrievable and amenable to statistical analysis dictated the use of a computerized data system.

Many of the factors incorporated in the data forms were simple "identification" type factors which required the investigator to identify characteristics of the environment, the motorcycle, other vehicle, rider, helmet, etc. To a certain extent these tended to be factors existing prior to the collision.

However, many of the unique aspects of accidents involved the combination of relative pre-crash positions, pre-crash motions, evasive actions, collision dynamics, rider kinematics and injuries, and helmet damage. The data forms had to satisfy the conflicting requirements to provide enough detail to define the major accident factors, yet not define so many detailed factors as to lose sight of the general characteristics of the accident. In other words, the data forms had to provide enough detail, but not too much.

The development of the data forms took place during the training period that preceded the collection of on-scene, in-depth accident data. Many of the factors selected for investigation were drawn from the research proposal. A given factor was selected, various possible responses were then identified and put into mutually exclusive multiple-choice categories. Somatic injuries were encoded using the Occupant Injury Classification (Marsh, 1973).

Because of the particular interest in head and neck injuries in motorcycle accidents, a new data form was developed to encode head and neck injuries with a higher degree of accuracy. The Head and Neck Injury form was based on the existing Occupant Injury Classification. Six elements defined each injury; the first three elements were locators which identified the location of the injury. "Region" was usually defined in terms of the nearest major bony structure. However, because some injuries might overlap a number of specific bones, more general locators such as "face", "cervical" (neck), and "brain" were included. The second and third locators identified the side of the body and the aspect (anterior, posterior, medial, etc.) on which the injury occurred. The fourth factor identified the injury type; the fifth identified the system or organ or region involved. The sixth factor assigned an injury severity score which was taken from the Abbreviated Injury Scale (American Association for Automotive Medicine, 1976). Side, aspect and injury-type codings were taken directly from the Occupant Injury Classification. This system proved to be quite flexible in encoding a wide range of head injuries. Of course, some detail is lost. The system does not allow the separate specification of say, sternomastoid muscle injuries from sternohyoid muscle injuries in the anterior neck, or to distinguish lesions of the midbrain raphe nuclei from those of the locus coeruleus. However, such distinctions are not critical for the present research purposes: muscle injuries do not represent a threat to life, and brain injuries tend to be rather diffuse and not restricted to a single cytoarchitectonic region.

When the data forms had been developed they were utilized for practice accident investigation activities in exactly the same way they would be used for the collection of the research data. This allowed team members to modify the forms to accommodate unanticipated accident characteristics and to develop uniform intercoder practices.

Practice Team Operations

The training period culminated in the collection of approximately fifty on-scene, in-depth accident investigations purely for purposes of practice at the data collection and evaluation methods that had been learned or developed during the training period. This also served to refine the data forms that would be used for coding accident information during the data collection phase.

Exposure Task

The collection of motorcycle exposure data did not entail a formal training period for the personnel involved in the on-scene exposure data collection. The primary reason was that in the majority of exposure cases, at least one of the data collectors was also experienced in the collection of on-scene, in-depth accident data. Because the exposure data questions were virtually identical to the accident data questions, and the same logic of responses applied to both, the tasks were highly similar and there was a very high level of transfer from one task to another.

Training of personnel who did not have experience in accident data collection was by explanation and demonstration of the accident data collectors. Further, accident investigation personnel were always available for consultation in complex issues and performed a large part of the exposure data quality control.

4.3 Sampling Plan

Details of the original sampling plan are available in the Phase I Report (Hurt, 1976). Essentially, the sampling plan called for the following:

1. The collection of 3600 traffic accident reports from the Los Angeles Police Department and California Highway Patrol and the encoding of the information on the reports. The sampling period was defined as January, 1976 through July, 1977 (when it was estimated the 3600 goal would be achieved). This plan would simply sample all reported accidents occurring in the study area.

2. The on-scene, in-depth investigation of 900 motorcycle accidents in the same time period. Accidents were to be collected according to a sampling plan detailed in the Phase I Report.

3. The exposure data were to be collected on the same day of the week, same time of day, under similar weather conditions one week after the accident occurred. There were to be 900 exposure sites, one for each accident investigated in depth by the team. This was later modified to 505 sites.

Police Reports

The data from the 3600 traffic accident reports were collected in accordance with the plan outlined in the Phase I Report. Accident research personnel stopped regularly at California Highway Patrol offices, where all motorcycle accident reports were held for pickup. A similar method of picking up reports from the various divisions of the Los Angeles Police Department also was used. Additionally, the computerized accident reporting system of the City of Los Angeles allowed the identifiation of all traffic accident reports involving a motorcycle. A computer print-out showing the location and report number of all motorcycle accidents was obtained on a semi-annual basis. This was crosschecked against reports already collected by the team and any missing reports were obtained from the Records Division of the Los Angeles Police Department.

Accident Data

The collection of on-scene, in-depth (OSID) data took place during the entire 1976 and 1977 calendar years. Approximately 1100 investigations were initiated and 900 of these were completed. In practice, the notification system, even at maximum effectiveness, provided notification of only about one-fourth of the recorded accidents, and this level of notification required more than six months to achieve. This dearth of notifications precluded the sampling of accidents to meet any predetermined sampling system; virtually all radio and telephone notifications of accidents were investigated and completed. The only limitation presented was saturation of team capability. The collection of accidents after notification allowed the team to collect accidents occurring during the hours when the team was

not on duty. The difficulty in immediate notifications also required the extension of the data collection period from August, 1977 to December, 1977 in order to acquire the full 900 accident cases for completion of data requirements.

Exposure Data

As a result of delays in procurement and funding, the collection of exposure data was modified in two ways: 1) rather than being collected as soon as possible after the accident, the exposure data were collected from June, 1978 through June, 1979, and 2) data was collected at 505 accident sites, rather than all 900 accident sites. Exposure sites were selected from the accident sites on a random basis.

In the collection of rider and motorcycle information at each exposure scene, the sampling plan was simply to photograph all motorcycles and riders and, if the traffic flow and roadway permitted stopping riders for interviews, team personnel attempted to attract and interview every passing motorcycle rider. Of course, some exposure sites, such as freeways and major arterials without curbside parking, did not lend themselves to interviewing, and many riders simply refused to stop or gave only limited information about themselves.

4.4 Field Data Collection Activities

Whenever notification of an accident was received, the team responded immediately to the scene of the accident in conspicuously marked research vehicles. On arrival at the scene, contact was immediately made with the investigating officer to gain access to the accident scene. The highest priority was given to collection of perishable data: The involved car was photographed to define the collision damage including motorcycle and rider impact areas, the car driver was interviewed, the environmental evidence was photographed and later diagrammed. The motorcycle was examined and photographed. Information about the motorcycle that could not be determined from photographs, such as brake adjustment, tire pressure, etc., was determined and recorded on scene.

Environmental Evidence

Evaluation of the environmental factors began with the location and careful examination of the motorcycle and other vehicle precrash paths of travel. This allowed evaluation of the roadway for view obstructions, pavement irregularities, precrash lines-of-sight, conspicuous marks of precrash evasive actions, solar glare, etc. Following this evaluation, photographs were taken along the precrash paths of travel (insofar as traffic conditions allowed) to document the findings. Diagrams of the accident scene were drawn to show the pertinent evidence and define distances. Finally, environmental data forms were completed at the scene or later during office review of scene photographs.

Vehicle Evidence

Because automobiles involved in a collision with a motorcycle were usually driveable, the driver of the other vehicle usually left the scene soon after the accident. The other vehicle was usually the first item photographed by the team personnel at accident scenes. Evaluation of the automobile was restricted to the photography of accident damage in instances where drivers were unwilling to be

interviewed. In follow-up investigations, the automobile had to be located then examined and photographed. In some instances, repairs had already started, so the damaged parts were located, examined, and photographed.

Examination of the motorcycle was most often completed at the scene of the accident. When this was not possible, the motorcycle was examined wherever it was available, e.g., a tow yard, impound lot, rider home, or a repair shop. The motorcycle was photographed and measured and information about it was recorded on the precoded data forms: identifying information such as manufacturer, type, year, size, etc., modifications, tire and wheel types and conditions, condition of maintenance, collision damage (as separate from general wear-and-tear and previous accidents). If a fire was involved, the fuel and ignition sources were determined and recorded. Tires were evaluated for scuffs and skid patches to identify evidence of braking and loss of control mode, for violation of tire or tube integrity, for debris trapped between tire and rim, for inflation pressures or tire wear contributing to loss of control, etc. In some instances, second and third follow-up examinations were necessary in order to resolve some critical question.

Human Factors - Interviewing

On-scene activity involved interviewing of the rider and passenger and other vehicle driver if they were available for interview. Witness interviews were often utilized to help establish the points of rest of the accident-involved vehicles and parties if such information could not be determined from physical evidence alone. Eyewitnesses to the accident were interviewed; their statements often guided the search for corroborating physical evidence. Of course, when physical evidence conflicted with witness statements, the witness statements were given less significance in favor of the physical evidence. For example, witnesses almost always overestimated motorcycle speeds, usually by 30% to 50%, and other vehicles drivers often improperly identified the precrash location of the motorcycle, or said it "came out of nowhere."

Motorcycle riders were usually interviewed shortly after the accident either at the scene or at the hospital. In fatal cases or those involving severe head injury, interviews were conducted with a family member, friend, riding partner, coworker or some other person who could provide authoritative information about the injured party. Riders who were seriously injured and unable to participate in an interview in the emergency room were usually interviewed later during their hospitalization. Of course, some riders managed to elude the research team.

Because much of the rider's background information was unverifiable except on the rider's word, interviewers were careful to cross-check information given in one answer by asking other similar questions, or asking for clarification. For example, a rider might say he had been riding motorcycles for ten years. More careful questioning, however, might reveal that two or three years of his experience, involved sporadic riding on borrowed motorcycles and another year of no riding at all. Obviously, these periods differ substantially from periods of owning and operating one's own motorcycles; as such they would not be counted as riding experience. Similarly, many riders who claimed to have dirt bike experience had only occasional dirt riding experience on borrowed motorcycles.

Rider statements about precrash and crash events, and evasive actions received the same careful scrutiny and cross-checking with physical evidence that other vehicle driver and witness statements received. For example, rider statements about their precrash evasive maneuvers seemed to reflect either their intended evasive action or some sort of wishful thinking; there was a low correspondence between rider statements and physical evidence indicating what evasive action had actually been taken (or, quite often not taken). Similarly, they often invented potholes, and sand or gas or oil spills on the roadway, and stuck throttles, to account for a fall to the pavement caused by their own lack of skill or some unsafe act. The explanations given by the riders were not really deliberate deception; rather, they represent the rider's efforts to reconstruct and make sense of a painful and bewildering experience.

Photography

Photography was the principal means of documenting evidence from the accidents. Equipment used were Canon FT and Nikkormat 35mm single lens reflex cameras equipped with standard 50mm f1.8 lenses (one Nikkormat had an 85mm f3.5 macrolens). Flash units were used not only in night photography but also for daylight flash-fill photography, in order to reduce the darkness of shadows cast by the sun on the motorcycle.

Photography of the accident scene demanded a series of photos along the motorcycle path of travel in order to document the roadway conditions — general environmental conditions as well as specific characteristics of the roadway as they appeared to the rider in the immediate pre-crash moments. Photos along the motorcycle path of travel also allowed the accurate documentation of skids and scrapes that helped define the pre-crash evasive actions or loss of control mode of the motorcycle, and the point of impact. If a vehicle involved in collision with the motorcycle left any skids these were similarly documented. Photos along the other vehicle pre-crash path of travel helped evaluate environmental conditions experienced by the car driver and the pre-crash conspicuity of the motorcycle (by showing the background against which the rider would have been seen).

Photography of the motorcycle involved overall shots of the standing motorcycle with eight views around the motorcycle: right, left, front, rear, right- and left-front, right- and left-rear. While numerous views created some redundancy of observation, it was not uncommon for one view to show some critical item that might not be apparent in another view. For example, bending of the rear shock by the rider's leg being trapped between the rear shock absorber and a car bumper might show up in a full right side view, but not a right-rear view. The eight documentary photographs were shot from about tank level and provided the elementary vehicle data for the motorcycle. Close-up photos were used sparingly to document specific critical data elements such as headlamp filament condition (indicating headlamp function at the instant of impact), tire striations indicative of braking, loss of control, etc., and hair, skin or cloth marks indicating rider contact; vehicle defects related to accident causation were also documented.

Photographs of the accident-involved automobile typically documented only the areas of the car sustaining impact either with the rider or the motorcycle. Close-up photos were usually unnecessary, although in some instances they were

used to illustrate critical data elements. For example, a pattern of motorcycle front tire striation on a car door might indicate use or non-use of the front brake: nearly horizontal scuffs in broadside impacts show a predominance of car motion but little tire motion, indicating that the tire had nearly stopped rolling as a result of braking at the moment of impact.

Helmet Analysis

Of course, the analysis of damage to the accident-involved helmet was a critical part of the accident investigation. Some elements of the analysis were straightforward: identification of the manufacturer, date of manufacture, standard certifications, construction materials, helmet type, retention system type, etc.

In many instances the objects struck by the helmet were easy to identify: pavement, tires, glass, and painted metal have characteristic patterns of marking the helmet shell. In other cases identifying a pattern of damage, or establishing a chronology of impacts was quite difficult. For example, a faint linear dent on a polycarbonate shell can be overlooked easily, or mistaken for light gouge; but if caused by direct pressure perpendicular to the shell, it represents an enormous crushing load. Similarly, abrasion damage to the edge bead of the helmet is common, and usually of no great significance, but slight discoloration and deformation can indicate severe impact forces. When the helmet strikes a soft compliant surface such as a car door, the impact load can be spread diffusely by the deformation of the sheet metal; hence crushing of the foam liner material of the helmet might be focally minimal but spread over a very wide area. In all instances, the analysis of helmet damage required detailed examination, identification of the impacting surface and the nature of the impact and the careful synthesis of the data.

When helmet ejection occurred, the analysis required determination of whether the helmet had been fastened before the accident and, if so, the retention system failure mode and the time in the collision sequence when the helmet came off. Details of the analysis of damage to accident-involved safety helmets are available elsewhere (Hurt, Ouellet, and Wagar, 1976; Ouellet, 1979).

Exposure Data

Exposure data were collected at the scenes of previously worked accidents, on the same day of the week, same time of day, and similar weather conditions. Exposure teams arrived at the exposure site an hour before the accident time of the reference accident case. In the ensuing half hour the appropriate traffic flows to be counted were identified and verified, camera equipment prepared, and signs to attract passing motorcycle riders were placed alongside the roadway upstream from the exposure site. The signs were 2½ ft x 3 ft white reflectorized sheet metal, with four inch black letters; the three signs read, in order, "Motorcycles Stop Ahead," "Motorcycle Safety Survey," and "Motorcycles Stop Here."

The gathering of exposure data began one half hour before the reference accident time and concluded one hour later. For example, if the reference accident occurred at 12:30, exposure data were collected from 12:00 to 1:00. Traffic flow was tabulated using manually operated tally counters mounted on a board. One cluster of counters was used to count traffic of the other vehicle path of travel (if there were another vehicle path separate from the motorcycle path of

travel). Each cluster contained one counter for each major category of vehicles: full and intermediate size cars, compact cars, sub-compact cars, pickups and trucks, large trucks and buses, and others.

Ordinarily, one data collector counted traffic while the other was responsible for photographing all the passing motorcycles and interviewing the riders. Whenever possible, two photos were taken of the motorcycle that failed to stop for interview: a front-side view that permitted identification of the major characteristics of the motorcycle and headlamp function and rider apparel; plus a rear view that would permit identification of the license plate so that the registered owner could be identified then contacted later by mail.

On-scene interviews were conducted with those riders who stopped. The questions were essentially identical to those asked in the accident study and the same methods of cross-verifying answers were used. The interviews were prefaced by an explanation of the purpose of the research, an offer of anonymity and privilege to the rider, and an explanation of the questions to be asked. During this initial phase of the interview, research personnel attempted to establish a rapport with interviewees and put them at their ease.

Some riders who did not stop for interview were identified by means of the motorcycle license plate. A questionnaire soliciting the same information taken in an interview was mailed to the home address of the registered owner. Questions were in a open-ended form. The questionnaires returned to the team were then reviewed and the data encoded as in roadside interviews.

Accident Reconstruction

The field collection of data was the critical first element in the research effort. The second task in each accident was the analysis of the evidence and synthesis of all the available information to reconstruct the sequence of collision events, speeds, collision dynamics, rider kinematics and injury mechanics, to determine the effect of motorcycle modifications, conspicuity, helmet function and its relation to head injury, etc. Essentially, every accident was a jigsaw puzzle, with a thousand or so data elements, that fit together in only one way; and while there were similarities among accidents, each case was unique. The task facing the investigator was to identify the critical data items and determine the interrelation of these elements and develop a coherent mental picture that related all elements that define exactly how the accident occurred.

At the start of reconstruction, the investigator has collected information including a police report, medical report, twenty or so photos of the accident scene and vehicles, a diagram of skids and other environmental information, and partially completed data forms that define some of the environmental, vehicle and human factors in the accident. The analysis of the accident proceeds then from the selection of those critical factors necessary to resolve a particular question that cannot be resolved by direct observation.

For example, speed analysis was sometimes a simple, and other times a very complex task. Suppose a motorcycle rider overbrakes for a turn, slides out, falls and slides to a stop on the pavement without hitting any other objects. Here, the determination of crash speed is based simply on the coefficient of friction

of the motorcycle sliding on pavement, the distance the motorcycle slid, and the elevation of the roadway. The initial speeds are estimated by use of conventional computations based on uniformly decelerated motion.

In some cases, multiple estimates of speed are available to confirm the results to the accident reconstruction. For example, if a motorcycle rider runs wide on an elevated curve such as a freeway overpass and falls to the ground below while his motorcycle slides to a stop on the roadway, the speed of the motorcycle can be calculated as above. The speed can also be calculated by measuring the horizontal distance travelled during the fall divided by the time required to fall.

Motorcycle and automobile collisions were much more complicated. A common measure of impact speed is deformation of front suspension of the motorcycle. However, the experiments that defined motorcycle deformation as a function of motorcycle crash speed utilized only stationary automobiles being struck by moving motorcycles in perpendicular impacts. In relating such information to a real accident, the investigator must take into account the angle of impact, relative speeds of the vehicles, vector components of the speeds, modifications of the front forks, braking performance, etc.

Similarly, the analysis of injuries required the determination of the exact manner in which the collision occurred, the relative motions of the vehicle(s) in the instants of impact, and determination of those objects the rider struck. When the rider was thrown from the point of impact, it was necessary to define those injuries that occurred as a result of initial impact with a car, and those that resulted from tumbling in the roadway, and perhaps impacting other objects. The analysis of injuries required familiarity with the typical mechanisms of injury that had been discovered in automobile accident investigation and the patterns of injury peculiar to motorcycles, e.g., groin injuries and lower leg fractures.

Determination of loss of control modes was based largely on the pattern of environmental evidence and damage to the motorcycle. For example, the typical locked rear wheel slide-out involves a skidmark that starts rather straight and narrow, gradually broadens as it curves to one side and becomes faint and disappears. As the skid disappears, it is accompanied in parallel by scrape marks as the side of the motorcycle contacts the pavement. The motorcycle typically shows a pattern of damage in which the rear tire shows striations and scuffing on the same side on which the motorcycle fell, sliding damage to the rear and side structures of the motorcycle, and turn signals bent in the direction of the fall.

By contrast, the front braking slide-out is indicated by a very wide and heavy skid mark usually ten to fifteen feet long, which hooks off to one side. Like a rear slide out, the front braking slide-out has a region in which the skid mark is overlapped and paralleled by scrape marks from the side of the motorcycle. The motorcycle front tire shows striations and scuffs, the front turn signals and headlamp are bent and abraded and the abrasions often are horizontal when the motorcycles is examined standing up (because there is usually less yawing of the motorcycle in front-lock slide-outs than in rear lock slide-outs).

On the other hand, rear slide-out loss of control sometimes ends in a high-side when the motorcycle rider releases the rear brake as the motorcycle is starting to slide out and fall. This allows the rear wheel to start rolling again, thereby gaining traction and throwing the motorcycle to an upright position and beyond so that it falls on the "high"side. The critical environmental information that defines a "high side" is a gap of several feet between the end of the skid and the start of the scrapes. The motorcycle will show a skid patch and scuff marks on one side of the tire but pavement damage to the engine, muffler, pegs etc. on the opposite side. Thus the field collection of the data required the judgement and skill to recognize critical items such as the overlap of skids and scrapes, while reconstruction required the interpretation of small clues that pinpointed the collision conditions.

The preceding discussion is not intended to provide an exhaustive description of the process of accident reconstruction; rather, it is intended to illuminate the variety of factors considered and some of the logic in the reconstruction of motorcycle accidents. A more thorough discussion of some of the factors involved is available elsewhere (Hurt, 1973; Ouellet, 1979).

4.5 Quality Control

The investigation and reconstruction of each accident required the determination of 582 questions involving 1045 data entries (human factors alone required 658 data entries). These ranged from simple identification factors, such as roadway type or motorcycle manufacturer, to highly complex issues such as injury contact surfaces, speed analysis, and the relation between helmet use and head injuries.

The large amount of data collected and the complexity of the effort required a high level of quality control to assure the validity and reliability of the data. Quality control procedures took place on virtually every level of the research effort including data collection and accident reconstruction, as well as editing of the data and statistical analysis. Rather than being a separate function performed in isolation from the other research tasks, quality control was a constant, ongoing process integrated into the research effort. Quite often, quality control findings in one level of the research led to the alteration of task performance on another level. For example, reconstruction of accidents to determine injury contact surfaces might reveal that the composition of photographs taken during data collection needed improvement to better illustrate the characteristics of the impact.

Data Collection

Quality control took place in the data collection effort in a number of ways. In gathering rider background information, responses given by the rider were often cross-checked against other responses, or clarification was sought. For example, a rider might say that he had been attending to traffic on the roadway in front of him in the precrash phase of the accident, yet be unable to explain how the car he struck went from being at the side of the roadway to being directly in his path without his having seen it move until too late. Similarly, a rider might say he rides "every day" and under closer questioning state that he really commutes daily and rides only five days a week.

Injury information was often double or triple-checked. Information might come from the investigator's direct observations at the hospital, conversation with the injured party, emergency room reports, follow-up checks by the team pathology consultants or team personnel, autopsy reports and so on. In many cases, information came from two or three of these sources which were cross-checked against each other. Additionally, investigation of other aspects of the accident sometimes suggested injuries that were not immediately obvious. For example, some riders were reluctant to admit to having groin injuries, but when told that the motorcycle fuel tank showed damage characteristic of groin impact, they would usually concede to having suffered such an injury then provide other information about that injury.

Of course, interviews with accident-involved parties generated a variety of conflicting statements as to how the accident happened. As noted earlier, these statements were often used as a guide in searching for corroborating physical evidence, and in many cases led to the discovery of valuable physical evidence. Where physical evidence contradicted witness statement, the witness statement was discounted, and when no evidence could be found to support or contradict witness statements, the statements were evaluated in the larger context of the accident.

Motorcycle damage and environmental evidence show a correspondence in which damage and markings on the motorcycle caused by the environment should be identifiable within the environment and evidence in one should suggest evidence in the other. For example, in an accident in which the motorcycle ran wide on a turn, investigation of the environment may reveal tire scuffs along the curb. In order to verify that the scuffs came from the accident-involved motorcycle, the investigator would then look on the motorcycle tires and wheels for corresponding concrete abrasions that would confirm a low-angle tangential impact with the curb.

Quality Control in Reconstruction

In the early phases of the data collection, the reconstruction and review of the cases was performed jointly by all the investigators who had worked a particular accident. The debates occurring during such team reviews served to sharpen the reconstruction skills of the investigators and also allowed for development of standardization in resolving issues and encoding complicated information. During the later phases of data collection, reconstruction and review of the cases was typically performed by a single investigator with input from other investigators on the case as needed.

Many of the quality control procedures used in data collection were also used in the reconstruction and review of the cases. Since photographs were the principal means of documenting accident evidence, photographs were consulted extensively and cross-checked to verify evidence in the reconstruction of the accident for speeds, injury contact surfaces, collision kinematics and dynamics. Followup calls to accident-involved parties and witnesses were made as needed to clarify unresolved questions. In some cases, consultation was made with the treating physician to resolve questions concerning the rider's injuries, and in other cases outside physicians were consulted to help clarify complex issues relating to injuries.

Principal Investigator and Consultant Review

When team review and reconstruction of a case was complete the case was sent to the Principal Investigator for final review. Here, many of the same procedures used in reconstruction of the accident were utilized: evidence in photographs was carefully evaluated and cross-checked to verify precrash speeds and evasive actions, injury contact surfaces and collision dynamics. Data forms were checked for the internal consistency e.g., if the vehicle form stated that the front brake was being applied at the time of the accident, the human factors form should also indicate front brake usage as an evasive action. Review of all cases by the Principal Investigator also helped assure uniformity of coding practices.

Additionally, in a large number of cases, accident-involved parties were contacted by the Principal Investigator and interviewed a second time. This helped to verify information given in the original interview and allowed clarification of information contained in the field notes. Further, particular items of interest that arose in the course of the research were investigated on an informal basis. For example, many other vehicle drivers were surveyed to determine the extent of their familiarity and involvement with motorcycles, and a number of motorcycles riders were queried to determine the conspicuity characteristics of their upper torso coverage.

Quality Control in Data Processing

When quality control review by the Principal Investigator had been completed, the data were keypunched. Of course, any data identifying particular individuals, vehicles, accident locations etc. was excluded at this point to assure the inaccessibility of information regarding a particular accident. This was done to protect the anonymity of the accident-involved parties and the privileged research. In order to assure the reliability of the keypunch work, each case was keypunched then key verified. Any discrepancies that arose in data entries between the two sets of keypunch data were resolved by careful checking of the accident data forms to determine the proper entry.

When all cases had been keypunched and stored on tape, the next step of quality control was to take simple frequency counts of the responses to each question. Incorrect entries were then identified, checked against the case data form, the error resolved, and the data entry corrected. This process of generating the simple frequency counts, locating and correcting improper data entries, resolving the error and correcting the data entry was performed several times.

Finally, cross-tabulations of various data elements were made and unusual data entries were examined to determine the validity of the entry. Some entries required correction while other unusual entries simply reflected accident circumstances that were extraordinary in some way.

4.6 Data Processing and Analysis

Data collected in the study were encoded on the precoded field data forms. The data form usually contained a question about a particular item and a set of numbered multiple-choice responses. The investigator selected the appropriate response and entered the corresponding number in a box printed next to the question. When the case had been completed and all reconstruction and review by the team and Principal

Investigator was finished, the data entries were transferred from the data forms to keypunch cards. Each case was keypunched and key verified so that inconsistent entries were noted and resolved. When keypunch was completed, the data was transferred to magnetic disk for data processing and storage.

The data described in this report were stored as four independent sets:

1. 3600 Traffic accident report cases

2. 900 On-Scene, In-Depth accident cases

3. 505 exposure site data cases

4. 2310 motorcycle and rider exposure data cases

While the four sets were independent it was possible to transfer data from one to another. For example, the 505 exposure site data forms did not specify the intersection type. However, since each exposure took place at the same scene as a previous on-scene, in-depth accident, it was possible to transfer that data element from the reference accident case to the exposure data.

All file creation and manipulation programs were built using Fortran IV and the statistical analysis programs were built using the Statistical Package for the Social Sciences (SPSS). Since there were four independent data sets, four separate SPSS programs were built - one for each data set.

Additionally, the injury data from the 900 OSID cases were subdivided into two subsets: somatic injuries — defined roughly as anything below the neck — and head and neck injuries. Somatic injuries were encoded using the Occupant Injury Classification (OIC). Head and neck injuries were encoded using a system similar in form to the OIC but differing in the body part associated with a particular code. For example, in somatic injuries the body region designated "P" is the pelvis; and the head and neck injury form "P" signifies "parietal". Obviously, somatic injuries were encoded and analyzed completely independent of head and neck injuries, and vice versa.

Statistical analysis of the data was largely through SPSS methodology. Simple frequency counts were made on all variables and, when the interaction of two factors was the object of interest, a cross-tabulation of all the various responses was generated. Specific questions required specific collection and cross-tabulations for analysis.

In many instances, a chi-square test might not show statistical significance within a large cross-tabulation since data were very often nominal as opposed to ordinal or interval in nature. Nevertheless, it may be highly significant in a non-statistical sense that, for example, one accident in twelve involved undercornering and running wide on a turn while one in thirty involved overcornering and grounding out.

An important part of the data analysis involved determination of the nature and severity of the most severe injury. Each accident could have no injuries (in which case the most severe injury is "none" and the severity "0"), or there could be one or more injuries. Of course, a rider could have some injuries with the

same severity levels. For example, the rider might have six somatic injuries with the following severity scores: 1,1,3,1,2,3. The format followed in selecting the most severe was as follows:

1. Arrange all injuries in order of increasing severity. In the example above, this would be: 1,1,1,2,3,3.

2. Select the <u>last</u> injury on the list as the most severe injury.

When there is more than one injury at the highest severity level, as in the above example, the particular injury selected as "most severe" is somewhat arbitrary. However, it is precisely this arbitrariness that assures against selective bias in designating one injury (among two or more possibilities) as the "most severe".

Some of the data analyses involved collapsing data elements into smaller categories. For example, age was tabulated on a year-by-year basis. But a cross-tabulation of, for example, helmet use by age is cumbersome and any trends within the data may be unclear until the 50 individual year categories are collapsed into several groups - in this example 0-16 years, 17-20, 21-26, 27-39, 40-49, 50-59, 60-97 years. When cumbersome data is treated in this manner, basic trends may be more readily apparent, and this type of treatment has been used in this report.

4.7 Research Recommendations

This research demanded a special qualification for the staff: It was mandatory that the research team members have extensive motorcycle experience in addition to the professional qualifications. It was vital that the research team members have the experience, perspective and sensitivity to the special problems of the motorcycle rider and the special characteristics of motorcycle accidents. It is sure that without this special ingredient, the factors critical to motorcycles would NOT have been collected with fidelity.

The comparisons of exposure data and registration data showed great differences. Actual motorcycle use differs greatly from registration information, e.g., many registered motorcycles are stored or are in garages and are not actually in use on the street by those licensed riders. Also, the use of traffic accident reports for motorcycle accident research must be limited. Only very basic information is available from such casual and perfunctory investigation; speeds, collision contacts, injury analysis, culpability, etc. can not be related with acceptable accuracy.

The chronological defect of the exposure data caused difficulty and had the prospect of reducing the effectiveness of the research findings. Most of the major factors of concern in this research were protected by benchmark data or special analysis. Nevertheless, all accident data collection should be accompanied by timely exposure data collection.

The urban populations have changed greatly during the last ten years and it is typical that data collection teams will be required to demonstrate some fluency in Spanish.

Any future research on motorcycle accidents should include more in-depth examination of characteristics of the driver of the other vehicle involved in collision with the motorcycle. The dominant culpability of the driver of the other vehicle shown in these data demands further detailed examination to determine concisely the causes of the search and detection failures.

5.0 ACCIDENT CHARACTERISTICS AND ENVIRONMENTAL FACTORS

This section of the accident data shows the characteristics of the accidents and the contribution of the environmental factors in the accident events. The single and multiple vehicle accidents are analyzed for the accident time, accident configuration, cause factors and the contribution of the environment to those causes. For example, in the case of the multiple vehicle collision, it is shown that the driver of the other vehicle is most often the culpable party in the accident by violating the right-of-way of the oncoming motorcycle, usually as a result of a detection failure. The adjacent traffic and buildings contribute to the inability of the other driver to detect the motorcycle in traffic, but the significant item is the lack of conspicuity of the motorcycle in traffic. Those factors relating to the lack of conspicuity are investigated in special detail to show the effect of the visibility contribution of the upper torso garment worn by the motorcycle rider.

5.1 USC Accident Data Acquisition

Table 5.1.1 shows the performance of the USC-DOT research teams in the collection of motorcycle accident data. Of the 900 on-scene, in-depth accident cases, (OSIDs), 68.6% were investigated at the accident location as soon as possible after the occurrence of the accident. In this way, the vehicles and most human subjects were still at that location. The remaining 31.4% of the detailed investigations were conducted by follow-up activities within 24 hours after the accident occurrence.

TABLE 5.1.1 TYPE OF INVESTIGATION BY USC (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
On-Scene	1.	617	68.6	68.6
Follow-up in 24 hours	2.	283	31.4	3.14
	TOTAL	900	100.0	100.0

The traffic accident reports (TARs) for motorcycle accidents in the study area were collected on a regular basis from the law enforcement jurisdictions in the study area. A total of 3600 were coded and prepared for analysis and approximately 320 others have been collected for additional reference. There were no omissions in this collection procedure, and subsequent data comparisons showed that this file represented 100% of the reported accidents in the study area at that time.

5.2 Accident Distribution by Time, Day, and Month

Tables 5.2.1 and 5.2.2 show the distribution of the accidents by the time of day with the greatest concentration of all accidents in the time of 3 to 6 PM.

TABLE 5.2.1. TIME OF DAY OF ACCIDENTS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
0001 thru 0100	1.	12	1.3	1.3
0101 thru 0200	2.	6	0.7	0.7
0201 thru 0300	3.	11	1.2	1.2
0301 thru 0400	4.	7	0.8	0.8
0401 thru 0500	5.	2	0.2	0.2
0501 thru 0600	6.	2	0.2	0.2
0601 thru 0700	7.	14	1.6	1.6
0701 thru 0800	8.	17	1.9	1.9
0801 thru 0900	9.	33	3.7	3.7
0901 thru 1000	10.	34	3.8	3.8
1001 thru 1100	11.	34	3.8	3.8
1101 thru 1200	12.	64	7.1	7.1
1201 thru 1300	13.	92	10.2	10.2
1301 thru 1400	14.	67	7.4	7.4
1401 thru 1500	15.	80	8.9	8.9
1501 thru 1600	16.	93	10.3	10.3
1601 thru 1700	17.	89	9.9	9.9
1701 thru 1800	18.	78	8.7	8.7
1801 thru 1900	19.	43	4.8	4.8
1901 thru 2000	20.	45	5.0	5.0
2001 thru 2100	21.	33	3.7	3.7
2101 thru 2200	22.	23	2.6	2.6
2201 thru 2300	23.	9	1.0	1.0
2301 thru 2400	24.	12	1.3	1.3
	TOTAL	900	100.0	100.0

The fatal accidents (54) were well distributed throughout the 24 hours without significant concentration.

Correlation was made with the data from the traffic accident reports and the on-scene investigations. Approximately 10% of the on-scene, in-depth cases did not have a traffic accident report prepared because of limited damage to the other vehicle, limited property damage, or limited injuries to the motorcycle rider. It is suspected that many other single vehicle motorcycle accidents occurred and were not recorded with traffic accident reports and are unknown in public record because of injuries to the rider only.

TABLE 5.2.2. TIME OF DAY OF ACCIDENT (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
0001 thru 0100	1.	89	2.5	2.5
0101 thru 0200	2.	57	1.6	1.6
0201 thru 0300	3.	52	1.4	1.4
0301 thru 0400	4.	25	0.7	0.7
0401 thru 0500	5.	8	0.2	0.2
0501 thru 0600	6.	13	0.4	0.4
0601 thru 0700	7.	52	1.4	1.4
0701 thru 0800	8.	134	3.7	3.7
0801 thru 0900	9.	91	2.5	2.5
0901 thru 1000	10.	93	2.6	2.6
1001 thru 1100	11.	127	3.5	3.5
1101 thru 1200	12.	155	4.3	4.3
1201 thru 1300	13.	263	7.3	7.3
1301 thru 1400	14.	201	5.6	5.6
1401 thru 1500	15.	253	7.0	7.0
1501 thru 1600	16.	291	8.1	8.1
1601 thru 1700	17.	374	10.4	10.4
1701 thru 1800	18.	345	9.6	9.6
1801 thru 1900	19.	228	6.3	6.3
1901 thru 2000	20.	195	5.4	5.4
2001 thru 2100	21.	194	5.4	5.4
2101 thru 2200	22.	138	3.8	3.8
2201 thru 2300	23.	132	3.7	3.7
2301 thru 2400	24.	85	2.4	2.4
Not Reported	98.	5	0.1	MISSING
	TOTAL	3600	100.0	100.0

Tables 5.2.3 and 5.2.4 show the accident distribution by day of week with Friday accounting for the greatest concentration.

Tables 5.2.5 through 5.2.8 show the months of accident occurrence for the data acquired. These data are included to illustrate acquisition performance and are not necessarily representative of the distribution of all such accidents. However, these data portray the typical concentration of accidents during the summer months of June, July, and August.

5.3 Objects Involved in Collision with Motorcycles

Table 5.3.1 shows those objects involved in collision contact with the motorcycles in the 900 on-scene, in-depth accident cases. Of the cases shown,

TABLE 5.2.3. DAY OF THE WEEK (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Monday	1.	137	15.2
Tuesday	2.	132	14.7
Wednesday	3.	145	16.1
Thursday	4.	128	14.2
Friday	5.	153	17.0
Saturday	6.	110	12.2
Sunday	7.	95	10.6
	TOTAL	900	100.0

TABLE 5.2.4. DAY OF THE WEEK (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Monday	1.	498	13.8
Tuesday	2.	492	13.7
Wednesday	3.	525	14.6
Thursday	4.	493	13.7
Friday	5.	590	16.4
Saturday	6.	524	14.6
Sunday	7.	478	13.3
	TOTAL	3600	100.0

TABLE 5.2.5. MONTH OF ACCIDENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
January	1.	52	5.8
February	2.	51	5.7
March	3.	63	7.0
April	4.	87	9.7
May	5.	66	7.3
June	6.	88	9.8
July	7.	109	12.1
August	8.	107	11.9
September	9.	75	8.3
October	10.	76	8.4
November	11.	63	7.0
December	12.	63	7.0
	TOTAL	900	100.0

TABLE 5.2.6. MONTH OF ACCIDENT (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
January	1.	319	8.9
February	2.	340	9.4
March	3.	389	10.8
April	4.	394	10.9
May	5.	327	9.1
June	6.	403	11.2
July	7.	320	8.9
August	8.	237	6.6
September	9.	212	5.9
October	10.	246	6.8
November	11.	226	6.3
December	12.	187	5.2
	TOTAL	3600	100.0

TABLE 5.2.7. MONTH OF ACCIDENT (1976 TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
January	1.	166	4.6
February	2.	140	3.9
March	3.	183	5.1
April	4.	185	5.1
May	5.	199	5.5
June	6.	247	6.9
July	7.	251	7.0
August	8.	235	6.5
September	9.	212	5.9
October	10.	246	6.8
November	11.	226	6.3
December	12.	187	5.2
(1977 Accidents)	0.	1123	31.2
	TOTAL	3600	100.0

TABLE 5.2.8. MONTH OF ACCIDENT (1977 TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
January	1.	153	4.2
February	2.	200	5.6
March	3.	206	5.7
April	4.	209	5.8
May	5.	128	3.6
June	6.	156	4.3
July	7.	69	1.9
August	8.	2	0.1
(1976 Accidents)	0.	2477	68.8
	TOTAL	3600	100.0

TABLE 5.3.1. OBJECT STRUCK BY MOTORCYCLE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Passenger Car	1.	588	65.3
Other Motorcycle	2.	27	3.0
Fixed Object	3.	40	4.4
Animal	4.	8	0.9
Roadway	5.	172	19.1
Other 4-wheel Vehicle	6.	48	5.3
Other	7.	17	1.9
	TOTAL	900	100.0

230 were single vehicle collisions (Table 5.3.2) where the motorcycle did not make contact with another vehicle. The 230 cases were as follows:

Fixed Object	40
Animal	8
Roadway	172
Others (pedestrians, trash, etc.)	10
TOTAL	230

TABLE 5.3.2. MULTIPLE OR SINGLE-VEHICLE COLLISION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Single Vehicle Collision	1.	230	25.6	25.7
Multiple Vehicle Collision	2.	667	74.1	74.3
Unknown	8.	3	0.3	Missing
	TOTAL	900	100.0	100.0

In some of the 230 single vehicle collisions, another vehicle was involved in accident causation, e.g., an automobile turns left in front of the oncoming motorcycle, the motorcycle rider over-brakes, slides out and falls to the roadway but does not collide with the automobile. Forty-nine such cases occurred so that there were 181 cases where only the motorcycle was involved.

Table 5.3.3 shows the number of vehicles involved from the 3600 police traffic accident reports. Table 5.3.4 shows the collision type for those 3600 accidents. There is generally no precise distinction made for collision

TABLE 5.3.3. NUMBER OF VEHICLES INVOLVED (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Single Vehicle Accident	1.	803	22.3
Two Vehicles	2.	2709	75.2
Three Vehicles	3.	79	2.2
Four Vehicles	4.	7	0.2
Five Vehicles	5.	2	0.1
	TOTAL	3600	100.0

TABLE 5.3.4. COLLISION TYPE (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Head-On	1.	174	4.8	6.3
Rear-End	2.	548	15.2	19.9
Side-Swipe	3.	236	6.6	8.6
Angle	4.	1061	29.5	38.6
Broadside	5.	673	18.7	24.5
Others	6.	59	1.6	2.1
Unknown	8.	54	1.5	Missing
N.A. Single Vehicle Accident	9.	795	22.1	Missing
	TOTAL	3600	100.0	100.0

contact and, as a result, many of the single vehicle accidents may yet involve another vehicle in causation but not collision contact.

5.4 Accident Precipitating Factor

Table 5.4.1 shows the accident precipitating factors for the 900 on-scene, in-depth accident investigation cases. For simplicity, this factor may be considered to be the primary factor of accident causation. Table 5.4.2 shows the accident precipitating factor for the 230 single vehicle collisions and Table 5.4.3 shows the accident precipitating factors for the multiple vehicle collisions.

Phantom Vehicle was selected as the accident precipitating factor when the only evidence pointed to unsafe action of another vehicle which could be described but not identified. The unidentified phantom vehicle was NOT involved in collision contact with the motorcycle. As an example, one motorcycle rider

TABLE 5.4.1. ACCIDENT PRECIPITATING FACTOR (All OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Phantom Vehicle	0.	4	0.4	0.4
MC Error	1.	367	40.8	40.9
OV Violation of MC ROW	2.	457	50.8	50.9
Roadway Defect	3.	18	2.0	2.0
Pedestrian	4.	6	0.7	0.7
Animal	5.	10	1.1	1.1
Vehicle Failure	6.	25	2.8	2.8
Other	7.	11	1.2	1.2
Unknonwn	8.	2	0.2	Missing
	TOTAL	900	100.0	100.0

TABLE 5.4.2. ACCIDENT PRECIPITATING FACTOR
(Single Vehicle OSIDs Only)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Phantom Vehicle	0.	4	1.7
MC Error	1.	148	64.3
OV Violation of MC ROW	2.	25	10.9
Roadway Defect	3.	15	6.5
Pedestrian	4.	5	2.2
Animal	5.	9	3.9
Vehicle Failure	6.	21	9.1
Other	7.	3	1.3
	TOTAL	230	100.0

swerved to the right and off the straight roadway to avoid an oncoming, wrong-way automobile which was described but not identified by the rider, and there were no witnesses to support the claim that another vehicle was actually present. Generally, such claims about the phantom vehicle were vague and questionable and very difficult to support. In this way, it is difficult to classify such an accident but it is sure that there was only one vehicle involved in the collision, and that was the motorcycle. Hence, the classification here includes the phantom vehicle accident as a single vehicle collision. In addition, these "phantom vehicle" accidents are not large in number and conveniently fall into the group of single vehicle collisions.

Motorcycle Rider Error was selected as the accident precipitating factor when the accident evidence showed that the rider's actions were responsible

TABLE 5.4.3. ACCIDENT PRECIPITATING FACTOR
(Multiple Vehicle OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
MC Error	1.	219	32.8	32.9
OV Violation MC ROW	2.	430	64.5	64.7
Roadway Defect	3.	3	0.4	0.5
Pedestrian	4.	1	0.1	0.2
Animal	5.	1	0.1	0.2
Vehicle Failure	6.	3	0.4	0.5
Other	7.	8	1.2	1.2
Unknown	8.	2	0.3	Missing
	TOTAL	667	100.0	100.0

for the collision. As an example, an alcohol-involved motorcycle rider enters a curve at excess speed and runs wide on the turn, running off the roadway and crashing. In this case, the actions of the rider were the principal factors in the accident and the error would be assigned to the rider. Table 5.4.2 portrays the expected dominance of motorcycle rider error in the single vehicle collision, 64.3% of the 230 cases. Note also that in 10.9% of the single vehicle collisions, the other vehicle involved in the collision was at fault. Such a case would be represented by an automobile backing from a parking place into the right-of-way of an oncoming motorcycle. The motorcycle rider over-brakes, slides out and falls to the roadway without collision contact with the offending automobile. If there had been sufficient time and distance for the motorcycle rider to easily avoid collision by proper braking, the accident precipitating factor may have been determined as motorcycle rider error rather than the right-of-way violation by the automobile.

Other Vehicle Violation of the Motorcycle Right-of-Way is a predominating factor in the 900 on-scene, in-depth accident cases; 50.9% of all those accidents are attributable to the driver of the other vehicle involved in the accident. This fact is especially clear when the multiple vehicle collision data of Table 5.4.3 show that the 64.7% of those accidents are due to the actions of the driver of the other vehicle. The typical accident in this category is portrayed by the automobile in traffic turning left into the path of the oncoming motorcycle. In such an accident, the culpability is exclusively due to the action of the driver of the automobile. The greatest part of this accident cause factor is related to the failure of the automobile driver to "see" the oncoming motorcycle, or to "see it in time" to avoid the collision.

In the typical accident involving the automobile driver culpability, the post-crash statement of the automobile driver is "I signaled to turn left, and started out when it was clear. Then something hit my car and I later saw the motorcycle and the guy lying in the street; I never saw him! Look what he did to my car!" The motorcycle rider would usually say "all of a sudden this car pulled out in front of me. The driver was looking right at me!"

This dominant culpability of the driver of the other vehicle is a critical exposition of the failure to detect a relatively unfamiliar vehicle on a collision path where motion conspicuity is absent. It emphasizes the special need for high contrast conspicuity for the motorcycle and rider. A special sampling of 62 of these cases showed that there were no drivers of the accident involved automobiles who had any motorcycle experience; hence the motorcycle was an unfamiliar as well as inconspicuous target.

Roadway Defect was assigned when some severe irregularity of the roadway surface or traffic control was present. As shown by the accompanying data, this factor was closely related to a loss of motorcycle control and was most likely to cause a single vehicle collision. Whole roadway defects were only 2.0% of all 900 accidents, this factor appears as 6.5% of the single vehicle collisions. A typical accident of this sort would be the loss of control by an experienced motorcycle rider upon encountering a 1-1/2" pavement ridge nearly parallel to his path.

Pedestrian action was the precipitating factor when the pedestrian made some unsafe, darting move into the path of the motorcycle. This factor was chosen when it was clear that the pedestrian made this unsafe move away from traffic controls and crosswalks.

Animal involvement was selected as the accident precipitating factor when the animal in traffic was actually involved in the collision with the motorcycle, or was the principal hazard which caused action by the motorcycle rider, or other vehicle driver, and created the accident.

Vehicle Failure was chosen as the accident precipitating factor when mechanical performance of the motorcycle caused the accident. Vehicle failure was the principal factor in 2.8% of all the 900 accidents, and of course, those were primarily single vehicle collisions. Typical cases of vehicle failure involved puncture flats of the tires or a maintenance defect which caused loss of control.

Other was selected for those special cases where some strange circumstances did not allow concise determination of the accident cause. For example, a station wagon was struck in the side by an operating but RIDERLESS motorcycle which entered the intersection against traffic controls. No rider, passenger, or owner could be located for the motorcycle.

Table 5.4.4 shows the primary and secondary causes of the 3600 motorcycle accidents analyzed from traffic accident reports. A comparison of these data shows that only basic information on causation is available.

5.5 Pre-Crash Vehicle Motions

Table 5.5.1 (Appendix C.1) shows the precrash motions of the motorcycle and other vehicle involved in the 900 on-scene, in-depth accident cases. The outstanding elements of the data are as follows:

1. The most frequent accident configuration is the motorcycle proceeding straight and the automobile makes a left turn (most usually in front of the

TABLE 5.4.4. CAUSE OF ACCIDENT (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Primary				
No Cause Cited	0.	220	6.1	6.6
MC Driver	1.	1474	40.9	44.2
OV Driver	2.	1641	45.6	49.2
Unknown	8.	265	7.4	Missing
	TOTAL	3600	100.0	100.0
Secondary				
No Cause Cited	0.	3225	89.6	89.8
MC Driver	1.	268	7.4	7.5
OV Driver	2.	100	2.8	2.8
Unknown	8.	7	0.2	Missing
	TOTAL	3600	100.0	100.0

oncoming motorcycle). This configuration appears in 26.7% of all the accidents, or 33.4% of the multiple vehicle collisions.

2. The second most frequent accident configuration is with both vehicles proceeding straight, and this configuration appears in 10.9% of all the accidents.

Table 5.5.2 (Appendix C.1) shows the same details for the 230 single vehicle collisions. The involvement of the other vehicle in these data is that of causation only since no collision contact occurs. The outstanding elements for these data are as follows:

1. The most frequent configuration was the motorcycle proceeding straight in 60.0% of the motorcycle data.

2. The motorcycle is turning (right, left, or U-turn) in 35.2% of the motorcycle data.

Table 5.5.3 (Appendix C.1) shows the precrash motions for the motorcycle and the other vheicle involved in the 3600 accident cases analyzed from traffic accident reports. Case-by-case comparison of traffic accident reports showed that the traffic accident reports do not accurately portray the precrash vehicle motions. Of course, this disagreement is obvious from comparison of the data of Tables 5.5.1 and 5.5.3, and it is recommended that traffic accident report data not be relied upon to describe any detail of vehicle precrash motions. The typical traffic accident report is no substitute for the detailed information from a competent accident reconstruction.

Tables 5.5.4 (Appendix C.1) and 5.5.5 (Appendix C.1) show the precrash motion of the motorcycle and other vehicle as a function of accident precipitating factor. An important element of 5.5.4 is that the motorcycle precrash motion is straight in 87.3% of those cases where another vehicle violates its right-of-way. This fact demonstrates that the precrash collision geometry offers little - if any - motorcycle conspicuity due to motion and that conspicuity due to contrast is an essential element of accident prevention for the motorcycle rider. Also, the motorcycle precrash motion is straight in 47.4% of those cases where motorcycle rider error is the precipitating factor.

Table 5.5.5 shows the dominating condition of the other vehicle making a left turn when it violates the motorcycle right-of-way, 50.5% of that accident precipitating factor.

5.6 Accident Scene, Type of Area

The urban and suburban areas predominated in the 900 multidisciplinary accident investigation cases. Truly rural settings (undeveloped open land and rural locations) accounted for only 9.4% of the total cases. The data of Table 5.6.1 show that business-shopping areas were outstanding as accident

TABLE 5.6.1. ACCIDENT SCENE, TYPE OF AREA

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
OSIDs				
Industrial	1.	72	8.0	8.0
Business/Shopping	2.	334	37.1	37.2
Apartments	3.	84	9.3	9.3
Residential	4.	288	32.0	32.0
Undeveloped	5.	19	2.1	2.1
School	6.	36	4.0	4.0
Rural	7.	66	7.3	7.3
Unknown	8.	1	0.1	Missing
	TOTAL	900	100.0	100.0
TARs				
Industrial	1.	91	2.5	2.6
Business/Shopping	2.	2000	55.6	56.9
School/Playground	3.	13	0.4	0.4
Park/Recreation	4.	22	0.6	0.6
Residential	5.	1229	34.1	35.0
Rural/Agriculture	6.	6	0.2	0.2
Undeveloped	7.	151	4.2	4.3
Unknown	8.	88	2.4	Missing
	TOTAL	3600	100.0	100.0

locations for the 900 on-scene, in-depth accident cases. The data show the same dominating factor for the 3600 traffic accident report cases although there is no agreement in quantification. As in other data, case-by-case comparisons of the traffic accident reports and the on-scene data showed low reliability of the traffic accident report description of the area.

5.7 Accident Scene Illumination

Table 5.7.1 shows the data for accident scene illumination for the accident cases studied. Daytime and daylight conditions predominate in both sets of data. Note that very low light conditions are not a significant part of the accidents, i.e., about 3%.

TABLE 5.7.1. ACCIDENT SCENE ILLUMINATION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
OSIDs				
Daylight	1.	676	75.1	75.1
Dawn or Dusk	2.	59	6.6	6.6
Night-Lighted	3.	140	15.6	15.6
Night-Unlighted	4.	25	2.8	2.8
	TOTAL	900	100.0	100.0
TARs				
Daylight	1.	2438	67.7	67.8
Dusk-Dawn	2.	90	2.5	2.5
Dark-Unlighted	3.	110	3.1	3.1
Dark-Lighted	4.	932	25.9	25.9
Day-Dark-Cloudy	5.	27	0.7	0.8
Unknown	8.	3	0.1	Missing
	TOTAL	3600	100.0	100.0

5.8 Accident Scene Weather Conditions at Time of Accident

Table 5.8.1 shows the weather conditions at the accident scene at the time of the accident. Adverse weather is not a factor in the majority of the motorcycle accident data. The data for the 900 on-scene, in-depth investigations shows favorable weather (clear, cloudy or overcast) in 97.8% of those cases; the data for the 3600 traffic accident report analyses shows favorable weather in 97.1% of the accident cases.

TABLE 5.8.1 WEATHER CONDITIONS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
OSIDs				
Clear	1.	752	83.6	83.6
Rain	2.	9	1.0	1.0
Drizzle	3.	11	1.2	1.2
Cloudy/Partly Cloudy	7.	89	9.9	9.9
Overcast	8.	39	4.3	4.3
	TOTAL	900	100.0	100.0
TARs				
Clear	1.	3490	96.9	97.1
Rain	2.	59	1.6	1.6
Fog	3.	6	0.2	0.2
Others	4.	38	1.1	1.1
Unknown	8.	7	0.2	Missing
	TOTAL	3600	100.0	100.0

Of course, these accident data are clearly related to exposure conditions; motorcycle traffic essentially disappears in adverse weather conditions.

Table 5.8.2 shows the air temperature at the accident scene on the 900 on-scene, in-depth accident investigations.

TABLE 5.8.2. TEMPERATURE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
41 thru 50°F	5.	13	1.4	1.5
51 thru 60	6.	118	13.1	13.5
61 thru 70	7.	318	35.3	36.3
71 thru 80	8.	324	36.0	37.0
81 thru 90	9.	91	10.1	10.4
91 thru 100	10.	11	1.2	1.3
Unknown	98.	25	2.8	Missing
	TOTAL	900	100.0	100.0

5.9 Trip Plan, Motorcycle Rider and Other Vehicle Driver

The trip plan for the accident-involved motorcycle rider was determined for the 900 multidisciplinary accident cases. The origins and destinations are shown in Table 5.9.1 and in each of those tabulations, home and work predominate. The crosstabulation of motorcycle rider trip origin and destination is shown in Table 5.9.2 (Appendix C.1). This crosstabulation shows that the home and work transportation plans include 26.2% of the accidents. The home, work and shopping-errand transportation plans include 48.3% of the accidents.

TABLE 5.9.1. RIDER TRIP PLAN (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Origin				
Home	1.	315	35.0	38.3
Work	2.	163	18.1	19.8
Shopping	3.	89	9.9	10.8
Recreation	4.	77	8.6	9.4
Friends/Relatives	5.	120	13.3	14.6
Bar/Drinking Party	6.	18	2.0	2.2
School	7.	41	4.6	5.0
Unknown	8.	65	7.2	Missing
Not Applicable	9.	12	1.3	Missing
	TOTAL	900	100.0	100.0
Destination				
Home	1.	274	30.4	32.9
Work	2.	153	17.0	18.4
Shopping	3.	142	15.8	17.1
Recreation	4.	122	13.6	14.7
Friends/Relatives	5.	115	12.8	13.8
Bar/Drinking Party	6.	1	0.1	0.1
School	7.	25	2.8	3.0
Unknown	8.	55	6.1	Missing
Not Applicable	9.	13	1.4	Missing
	TOTAL	900	100.0	100.0

The length of the intended trip for the motorcycle rider is shown in Table 5.9.3. The median value of this intended trip is approximately 4 miles.

Section 5.10 describes the time from the trip origin to the accident location and the median value of that time is less than 6 minutes. Consequently it is typical that the accident situation is much more closely associated with the trip origin.

TABLE 5.9.3. LENGTH OF RIDER INTENDED TRIP (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
0 to 1 mile	1.	161	17.9	20.7
1.1 to 5 miles	2.	284	31.6	36.6
5 to 50 miles	3.	305	33.9	39.3
Over 50 miles	4.	27	3.0	3.5
Unknown	8.	123	13.7	Missing
	TOTAL	900	100.0	100.0

The trip plan for the other vehicle driver was determined for those multidisciplinary accident cases where another vehicle was involved. The origins and destinations are shown in Table 5.9.4 and in each of those tabulations, home and work predominate. The crosstabulation shows that the home and

TABLE 5.9.4. OTHER VEHICLE DRIVER TRIP PLAN (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Origin				
Home	1.	175	19.4	34.8
Work	2.	145	16.1	28.8
Shopping/Errand	3.	86	9.6	17.1
Recreation	4.	33	3.7	6.6
Friends/Relatives	5.	48	5.3	9.5
Bar/Drinking	6.	3	0.3	0.6
School	7.	13	1.4	2.6
Unknown	8.	173	19.2	Missing
Not Applicable	9.	224	24.9	Missing
	TOTAL	900	100.0	100.0
Destination				
Home	1.	169	18.8	33.1
Work	2.	107	11.9	21.0
Shopping/Errand	3.	121	13.4	23.7
Recreation	4.	38	4.2	7.5
Friends/Relatives	5.	66	7.3	12.9
Bar/Drinking	6.	2	0.2	0.4
School	7.	7	0.8	1.4
Unknown	8.	172	19.1	Missing
Not Appplicable	9.	218	24.2	Missing
	TOTAL	900	100.0	100.0

work transportation plans included 30.8% of the accidents. The home, work and shopping-errand transportation plans included 64.9% of the accidents. Table 5.9.5 (Appendix C.1) provides a crosstabulation of original and destination of the other vehicle driver trip plan.

5.10 Time Riding Before Accident

Table 5.10.1 shows the distribution of time riding from trip origin to the accident location. The median value for this distribution is approximately 0.1 hours or 6 minutes. The typical accident location in this study of the 900 accidents occurs relatively close to the origin of the trip, e.g., 21.2% occurred at the trip origin less than three minutes after the departure.

TABLE 5.10.1. TIME RIDING MOTORCYCLE BEFORE ACCIDENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Hours	0.0	174	19.3	21.2	21.2
	0.1	232	25.8	28.2	49.4
	0.2	151	16.8	18.4	67.8
	0.3	112	12.4	13.6	81.4
	0.4	12	1.3	1.5	82.8
	0.5	48	5.3	5.8	88.7
	0.6	9	1.0	1.1	89.9
	0.7	9	1.0	1.1	90.9
	0.8	6	0.7	0.7	91.6
	1.0	24	2.7	2.9	94.5
	1.1	1	0.1	0.1	94.6
	1.2	1	0.1	0.1	94.8
	1.3	4	0.4	0.5	95.3
	1.5	6	0.7	0.7	96.0
	1.7	1	0.1	0.1	96.1
	2.0	12	1.3	1.5	97.6
	2.5	2	0.2	0.2	97.8
	3.0	4	0.4	0.5	98.3
	3.5	2	0.2	0.2	98.5
	4.0	4	0.4	0.5	99.0
	5.0	5	0.6	0.6	99.6
	5.5	1	0.1	0.1	99.8
	6.0	1	0.1	0.1	99.9
	7.5	1	0.1	0.1	100.0
Unknown	9.8	78	8.7	Missing	100.0
	TOTAL	900	100.0	100.0	

Note that 94.5% of the accidents occurred within one hour. The conclusion available is that fatigue due to riding is not a factor in these accidents. Also, the short trip lengths related in Section 5.9 and these short riding times may be associated with low priorities for rider protective equipment such as safety helmets, eye protection , gloves, etc.

The distribution of riding time for the 54 fatal accidents shown in Table 5.10.2, and the characteristics are essentially the same as the entire 900.

TABLE 5.10.2. TIME RIDING MOTORCYCLE BEFORE ACCIDENT (OSID Fatals Only)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Hours	0.0	10	18.5	29.4	29.4
	0.1	8	14.8	23.5	52.9
	0.2	5	9.3	14.7	67.6
	0.3	7	13.0	20.6	88.2
	0.4	1	1.9	2.9	91.2
	0.5	1	1.9	2.9	94.1
	0.6	1	1.9	2.9	97.1
	1.0	1	1.9	2.9	100.0
Unknown	9.8	20	37.0	Missing	100.0
	TOTAL	54	100.0	100.0	

5.11 Motorcycle Roadway

Table 5.11.1 shows the description of the roadway that the motorcycle was traveling at the accident location. Major and minor arterials were the roadway traveled by the motorcycle in 55.9% of the 900 on-scene, in-depth accident cases. Freeway traffic routes accounted for 10.0% of the cases.

Table 5.11.2 shows the intersection type for the 900 on-scene, in-depth accident cases. Approximately two-thirds of the accidents occurred at intersections. This concentration of accidents at the area of intersections is not reflected by the data from analysis of the 3600 traffic accident reports. These data specify only 40.0% of the accidents as intersection related. Case-by-case comparison of the two sets of accident data showed that the traffic accident reports employed a strict geographic interpretation related to the point of impact in the collision. The on-scene, in-depth cases applied a more liberal interpretation of intersection or non-intersection traffic related events rather than strict geographic rules. Consequently, the data for the 900 on-scene, in-depth cases will more accurately represent the accident characteristics.

TABLE 5.11.1. ROADWAY MOTORCYCLE WAS TRAVELING (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Freeway Mainline	1.	61	6.8	6.8
Freeway On-ramp	2.	6	0.7	0.7
Freeway Off-ramp	3.	12	1.3	1.3
Freeway Transition	4.	9	1.0	1.0
Freeway Frontage, Service Road	5.	2	0.2	0.2
Arterials	6.	503	55.9	55.9
Non-Arterial	7.	271	30.1	30.1
Temporary	8.	1	0.1	0.1
Parking Lot	9.	8	0.9	0.9
Alley	10.	10	1.1	1.1
Driveway	11.	8	0.9	0.9
Other	12.	9	1.0	1.0
	TOTAL	900	100.0	100.0

TABLE 5.11.2. INTERSECTION TYPES

Category Label	Code	Absolute Frequency	Relative Frequency (%)
All OSIDs			
Non-Intersection	0.	296	32.9
"T" Intersection	1.	94	10.4
Cross Intersection	2.	340	37.8
Angle Intersection	3.	30	3.3
Alley or Driveway	4.	113	12.6
Offset Intersection	5.	23	2.6
Other	6.	4	0.4
	TOTAL	900	100.0
Fatal OSIDs Only			
Non-Intersection	0.	27	50.0
"T" Intersection	1.	4	7.4
Cross Intersection	2.	12	22.2
Angle Intersection	3.	2	3.7
Alley or Driveway	4.	9	16.7
	TOTAL	54	100.0
TARs			
Intersection	1.	1434	39.8
Non-Intersection	2.	2149	59.7
Unknown, Not Reported	8.	17	0.5
	TOTAL	3600	100.0

The 54 fatal cases show less association with intersections; the fatal accidents more often involved the motorcycle rider losing control by running off the road, usually on a curve.

Table 5.11.3 (Appendix C.1) shows the contamination of the motorcycle roadway along the motorcycle path in its tire tracks. There was no contamination in 92.1% of those accident cases and there was no contribution to accident causation. However, when oil was present in the motorcycle path, disaster was on the way and the contamination was usually the main contribution to causing a slide-out and fall to the roadway. It is also shown that vehicle residue, truck spills and construction accounted for 58.3% of the contamination.

Table 5.11.4 (Appendix C.1) shows that the motorcycle roadway was dry in at least 96.0% of all the accident cases.

Table 5.11.5 (Appendix C.1) shows the grade and alignment of the motorcycle road of travel. No cases were found related to deficient downhill braking performance or lack of uphill climbing performance of the vehicle. Also, no curves or corners were related to limits of vehicle performance. On the other hand, if any effect were present due to road grade and alignment, it was possibly related to visual obstacles (see Section 5.15). Note that the motorcycle roadway was level (81.3%) and straight (80.1%) in the great majority of the accident cases.

Tables 5.11.6 (Appendix C.1) and 5.11.7 (Appendix C.1) relate the lane space and lane position of the motorcycle in the precrash time.

5.12 Other Vehicle Roadway

Table 5.12.1 shows the description of the roadway that the other vehicle was traveling. Major and minor arterials were the roadway traveled by the other vehicle in 53.1% of those cases involving another vehicle. Freeway traffic routes accounted for 6.9% of the cases.

Table 5.12.2 (Appendix C.1) shows that the roadway for the other vehicle was dry and without contamination. There was no case where reduced roadway friction for the other vehicle caused the collision, or made the collision unavoidable by the other vehicle driver.

Table 5.12.3 (Appendix C.1) shows the grade and alignment of the other vehicle road of travel. As in the previous section 5.11, there were no cases related to deficient downhill braking or lack of uphill climbing or turning performance of the other vehicle. That other vehicle roadway was level (83.5%) and straight (87.5%) in the great majority of the accident cases.

Tables 5.12.4 (Appendix C.1) and 5.12.5 (Appendix C.1) relate the lane space and lane position of the other vehicle in precrash time.

TABLE 5.12.1. ROADWAY OTHER VEHICLE WAS TRAVELING (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Freeway Mainline	1.	33	3.7	4.7
Freeway On-ramp	2.	3	0.3	0.4
Freeway Off-ramp	3.	5	0.6	0.7
Freeway Transition	4.	5	0.6	0.7
Freeway Frontage, Service Road	5.	2	0.2	0.3
Arterials	6.	371	41.2	53.1
Non-Arterial	7.	245	27.2	35.1
Parking Lot	9.	3	0.3	0.4
Alley	10.	4	0.4	0.6
Driveway	11.	28	3.1	4.0
Not Applicable	99.	201	22.3	Missing
	TOTAL	900	100.0	100.0

5.13 Traffic Density

Moderate or heavy traffic was the situation at 59.2% of the accidents. The congestion associated with this traffic underlies the importance of obstacles to vision and the role of motorcycle conspicuity. Table 5.13.1 shows the frequencies of traffic.

TABLE 5.13.1. TRAFFIC DENSITY FOR MOTORCYCLE ROAD OF TRAVEL (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Light	1.	344	38.2	39.2
Moderate, No Congestion	2.	400	44.4	45.6
Heavy, Near Saturation	3.	133	14.8	15.2
Not Observed	8.	17	1.9	Missing
Not Applicable	9.	6	0.7	Missing
	TOTAL	900	100.0	100.0

5.14 Traffic Controls

Table 5.14.1 shows that the motorcycle roadway was uncontrolled at the location of 70.2% of the 900 accidents. A conventional traffic signal set was at the location of 25.5% of the accidents.

The accident-involved motorcycle violated the traffic control in 13.8% of the accidents where a traffic control was present.

TABLE 5.14.1. MOTORCYCLE ROADWAY TRAFFIC CONTROLS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Type Control				
None	0.	632	70.2	70.4
Stop Sign	1.	25	2.8	2.8
4-way Stop Sign	2.	3	0.3	0.3
Signal	3.	229	25.4	25.5
Officer	4.	2	0.2	0.2
Yield	6.	2	0.2	0.2
Pavement Marks	7.	2	0.2	0.2
Other	8.	3	0.3	0.3
Not Applicable	9.	2	0.2	Missing
	TOTAL	900	100.0	100.0
Did MC Violate Traffic Control?				
Yes	1.	36	4.0	13.8
No	2.	225	25.0	86.2
Not Observed	8.	4	0.4	Missing
Not Applicable	9.	635	70.6	Missing
	TOTAL	900	100.0	100.0
Was Signal Sensor Involved On Roadway?				
Yes	1.	1	0.1	0.4
No	2.	258	28.7	99.6
Not Applicable	9.	141	71.2	Missing
	TOTAL	900	100.0	100.0

A typical irritant to the motorcycle rider in traffic is the traffic signal which depends on his motorcycle operating the sensor. While the matter is certainly irritating when the motorcycle will not trip the signal for the rider, that problem has little accident involvement, 0.1% of all the accidents and 0.4% of the accidents where a sensor was involved.

Table 5.14.2 lists the traffic code violations attributed to the motorcycle rider as a result of the accident circumstances.

Table 5.14.3 shows that the other vehicle roadway was uncontrolled at 57.9% of the 900 accident scenes. A conventional traffic signal set was at the location of 28.4% of the accidents.

The other vehicle involved in the accident with the motorcycle violated the traffic control in 44.9% of the accidents where a traffic control was present.

TABLE 5.14.2. MOTORCYCLE VIOLATION OF TRAFFIC CODE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	487	54.1	54.4
Signals	1.	16	1.8	1.8
Lane Control	2.	32	3.6	3.6
Tailgating	3.	62	6.9	6.9
Passing	4.	41	4.6	4.6
Fail to Yield ROW	5.	34	3.8	3.8
Stop Sign	6.	13	1.4	1.5
Pedestrian ROW	7.	1	0.1	0.1
Improper Turn	8.	10	1.1	1.1
Improper Entry	9.	4	0.4	0.4
Fail to Signal	10.	2	0.2	0.2
Speed	11.	144	16.0	16.1
Parking	12.	1	0.1	0.1
Alcohol or Drugs	13.	19	2.1	2.1
Reckless Driving	14.	4	0.4	0.4
Speed Contest	16.	7	0.8	0.8
Open Container	17.	1	0.1	0.1
Bad Lights	18.	3	0.3	0.3
Bad Tires	22.	1	0.1	0.1
Illegal Passenger	23.	3	0.3	0.3
Other	97.	10	1.1	1.1
Unknown	98.	5	0.6	Missing
	TOTAL	900	100.0	100.0

Table 5.14.4 lists the traffic code violations attributed to the other vehicle driver as a result of the accident circumstances. Compare these data with those of Table 5.14.2 to distinguish the culpability of the driver of the other vehicle in violating the right-of-way of the motorcycle.

5.15 Precrash View Obstructions and Limitations to Vision

These items were evaluated separately in order to isolate fundamental accident environmental problems from the motorcycle conspicuity problem. The motorcycle conspicuity problem relates to seeing the motorcycle _if_ the view path is clear; this environmental problem defines the availability of that clear path of view.

Tables 5.15.1 and 5.15.2 describe the view obstructions and visibility limitations for the motorcycle rider in the time just before the collision. Note that parked or moving vehicles affect the motorcyclist's view of the traffic hazard. The last table of 5.15.2 shows the combined effects of stationary and mobile view obstructions and visibility limitations for the motorcycle rider. The three factors combine to prevent the rider's clear view of the traffic hazard in 23.5% of the accident cases.

TABLE 5.14.3. OTHER VEHICLE TRAFFIC CONTROL (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Type Traffic Control				
None	0.	404	44.9	57.9
Stop Sign	1.	91	10.1	13.0
4-way Stop	2.	2	0.2	0.3
Signal	3.	198	22.0	28.4
Officer	4.	2	0.2	0.3
Other	8.	1	0.1	0.1
Not Applicable	9.	202	22.4	Missing
	TOTAL	900	100.0	100.0
Did OV Violate Control?				
Yes	1.	129	14.3	44.9
No	2.	158	17.6	55.1
Not Observed	8.	4	0.4	Missing
Not Applicable	9.	609	67.7	Missing
	TOTAL	900	100.0	100.0

TABLE 5.14.4. OTHER VEHICLE VIOLATION OF TRAFFIC CODE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	194	21.6	27.3
Signals	1.	41	4.6	5.8
Lane Control	2.	49	5.4	6.9
Tailgating	3.	16	1.8	2.3
Passing	4.	4	0.4	0.6
Fail to Yield ROW	5.	283	31.4	39.8
Stop Sign	6.	45	5.0	6.3
Improper Turn	8.	29	3.2	4.1
Improper Entry	9.	12	1.3	1.7
Fail to Signal	10.	10	1.1	1.4
Speed	11.	13	1.4	1.8
Parking	12.	3	0.3	0.4
Alcohol or Drugs	13.	8	0.9	1.1
Reckless Driving	14.	3	0.3	0.4
Bad Lights	18.	1	0.1	0.1
Unknown	98.	1	0.1	Missing
Not Applicable	99.	188	20.9	Missing
	TOTAL	900	100.0	100.0

TABLE 5.15.1. MOTORCYCLE VIEW OBSTRUCTIONS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Stationary				
None	0.	776	86.2	86.2
Buildings	1.	10	1.1	1.1
Signs	2.	1	0.1	0.1
Vegetation	3.	18	2.0	2.0
Walls, Fences	4.	10	1.1	1.1
Hill	5.	6	0.7	0.7
Curve	6.	11	1.2	1.2
Parked Vehicles	7.	68	7.6	7.6
	TOTAL	900	100.0	100.0
Mobile				
None	0.	799	88.8	89.9
Vehicles	1.	88	9.8	9.9
Constructions	4.	2	0.2	0.2
Unknown	8.	11	1.2	Missing
	TOTAL	900	100.0	100.0

TABLE 5.15.2. MOTORCYCLE VISIBILITY AND PATH-VIEW LIMITATIONS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Visibility Limitations for MC				
None	0.	886	98.4	98.6
Fog	2.	1	0.1	0.1
Glare	5.	9	1.0	1.0
Other	6.	2	0.2	0.2
Not Applicable	9.	1	0.1	0.1
Unknown	8.	1	0.1	Missing
	TOTAL	900	100.0	100.0
MC Path View - Visual Obstructions				
None	0.	682	75.8	76.5
Yes	1.	209	23.2	23.5
Not Applicable	9.	9	1.0	Missing
	TOTAL	900	100.0	100.0

The crosstabulation of Table 5.15.3 shows the significant contribution of parked and moving vehicles to view obstructions.

TABLE 5.15.3. MOTORCYCLE MOBILE VIEW OBSTRUCTIONS BY STATIONARY VIEW OBSTRUCTIONS (OSIDs)

	Stationary Obstructions								
MC View Obstruction — Count Row Pct Col Pct Tot Pct	None	Buildings	Signs	Vegetation	Walls, Fences	Hill	Curve	Parked Vehicles	Row Total
None	690 86.4 89.8 77.6	10 1.3 100.0 1.1	1 0.1 100.0 0.1	17 2.1 100.0 1.9	9 1.1 90.0 1.0	6 0.8 100.0 0.7	10 1.3 100.0 1.1	56 7.0 83.6 6.3	799 89.9
Vehicles	77 87.5 10.0 8.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.1 10.0 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	10 11.4 14.9 1.1	88 9.9
Construction	1 50.0 0.1 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 -0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 1.5 0.1	2 0.2
Column Total	768 86.4	10 1.1	1 0.1	17 1.9	10 1.1	6 0.7	10 1.1	67 7.5	889 100.0

Tables 5.15.4 and 5.15.5 describe the view obstructions and visibility limitations for the driver of the other vehicle involved in the motorcycle accidents. As for the motorcycle rider, parked and moving vehicles affect the other vehicle driver's view of the hazard. The last table of 5.15.5 shows the combined effects of stationary and mobile view obstructions and visibility limitations for the driver of the other vehicle. These three factors combine to prevent the driver's clear view of the motorcycle in 32.2% of the accident cases which involved another vehicle.

The crosstabulation of Table 5.15.6 shows the significant contribution of parked and moving vehicles to view obstructions.

Table 5.15.7 shows the interaction of the combined obstructions and limitations to the precreash views of the traffic hazards. The outstanding result is that both the motorcycle rider and the driver of the other vehicle had no clear view of the hazard in 23.9% of those cases.

These findings provide important components for a traffic strategy for a motorcycle rider. The motorcycle rider must locate himself (or herself) in traffic to insure a clear path of view to all prospective hazards. If such location is not possible, every intersection offers the possible challenge of the motorcycle right-of-way.

TABLE 5.15.4. OTHER VEHICLE VIEW OBSTRUCTIONS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Stationary				
None	0.	558	62.0	80.1
Buildings	1.	17	1.9	2.4
Signs	2.	4	0.4	0.6
Vegetation	3.	21	2.3	3.0
Walls, Fences	4.	8	0.9	1.1
Hill	5.	6	0.7	0.9
Curve	6.	4	0.4	0.6
Parked Vehicles	7.	78	8.7	11.2
Other	9.	1	0.1	0.1
Unknown	98.	1	0.1	Missing
Not Applicable	99.	202	22.4	Missing
	TOTAL	900	100.0	100.0
Mobile				
None	0.	586	65.1	85.7
Vehicles	1.	97	10.8	14.2
Construction	4.	1	0.1	0.1
Unknown	8.	14	1.6	Missing
Not Applicable	9.	202	22.4	Missing
	TOTAL	900	100.0	100.0

A representative accident case illustrates this problem. A motorcycle is proceeding in the curb lane and a van is travelling ahead in the parallel fast lane. Approaching an intersection, another automobile in oncoming traffic waits until the van clears and turns left as it passes. The left-turning automobile then moves into the right-of-way of the motorcycle. In such case, the culpability is clearly that of the automobile driver but both the motorcyclist and automobile driver had view obstruction (the van) before the crash. The strategy appropriate for the motorcycle rider is to ride abreast, or ahead, or much farther behind the van so that he (or she) could see and be seen. The strategic position is important to insure a clear view of prospective challenges of right-of-way and high conspicuity should increase the likelihood of being seen.

According to Table 5.4.1, there were 457 cases where the other vehicle violated the motorcycle right-of-way. According to the data of Table 5.15.5, 221 accident cases had a significant limitation or obstruction of the view from the other vehicle to the motorcycle. This implies a considerable part of that accident precipitating factor is due to view limitation or obstruction.

TABLE 5.15.5. OTHER VEHICLE VISIBILITY/PATH VIEW LIMITATIONS (OSIDs)

Category	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Visibility Limitations				
None	0.	687	76.3	98.3
Fog	2.	1	0.1	0.1
Smoke	3.	1	0.1	0.1
Glare	5.	10	1.1	1.4
Unknown	8.	1	0.1	Missing
Not Applicable	9.	200	22.2	Missing
	TOTAL	900.	100.0	100.0
Visual Obstruction of OV Path View				
None	0.	465	51.7	67.8
Yes	1.	221	24.6	32.2
Not Applicable	9.	214	23.8	Missing
	TOTAL	900	100.0	100.0

TABLE 5.15.6. OTHER VEHICLE MOBILE VIEW OBSTRUCTIONS BY STATIONARY VIEW OBSTRUCTIONS (OSIDs)

Mobile View Obstruction	Count / Row Pct / Col Pct / Tot Pct	Stationary View Obstructions: None	Buildings	Signs	Vegetation	Walls, Fences	Hill	Curve	Parked Vehicles	Other	Row Total
None	Count	473	11	2	19	8	6	3	62	1	585
	Row Pct	80.9	1.9	0.3	3.2	1.4	1.0	0.5	10.6	0.2	85.7
	Col Pct	86.5	68.8	50.0	95.0	100.0	100.0	75.0	80.5	100.0	
	Tot Pct	69.3	1.6	0.3	2.8	1.2	0.9	0.4	9.1	0.1	
Vehicles	Count	73	5	2	1	0	0	1	15	0	97
	Row Pct	73.3	5.2	2.1	1.0	0.0	0.0	1.0	15.5	0.0	14.2
	Col Pct	13.3	31.3	50.0	5.0	0.0	0.0	25.0	19.5	0.0	
	Tot Pct	10.7	0.7	0.3	0.1	0.0	0.0	0.1	2.2	0.0	
Construction	Count	1	0	0	0	0	0	0	0	0	1
	Row Pct	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	Col Pct	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Tot Pct	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
		547	16	4	20	8	6	4	77	1	683
		80.1	2.3	0.6	2.9	1.2	0.9	0.6	11.3	0.1	100.0

TABLE 5.15.7. MOTORCYCLE-OTHER VEHICLE PRECRASH VIEW OBSTRUCTION (OSIDs)

Category	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	446	49.6	65.3
MC Path Only	1.	17	1.9	2.5
OV Path Only	2.	57	6.3	8.3
MC & OV Paths	3.	163	18.1	23.9
N.A., No OV	9.	217	24.1	Missing
	TOTAL	900	100.0	100.0

5.16 Animal Involvement

Of the 900 on-scene, in-depth accident cases, there were 10 cases, or 1.2%, involving animals. The animals involved were two small dogs, seven big dogs, and one cat. Three of the big dogs were pursuing the motorcycle rider, and eight cases involved the motorcycle making crash contact with the animal. The highest injury severity to the rider in animal-involved accidents was AIS-5. The data are shown in Table 5.16.1.

TABLE 5.16.1. ANIMAL INVOLVEMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Type				
Small Dog	1.	2	0.2	20.0
Large Dog	2.	7	0.7	70.0
Cat	3.	1	0.1	10.0
N.A.	9.	890	98.9	Missing
	TOTAL	900	100.0	100.0
Was Animal Pursuing Motorcycle?				
Yes	1.	3	0.3	30.0
No	2.	7	0.8	70.0
N.A.	9.	890	98.9	Missing
	TOTAL	900	100.0	100.0
Was Animal Struck by Motorcycle?				
Yes	1.	8	0.9	80.0
No	2.	2	0.2	20.0
N.A.	9.	890	98.9	Missing
	TOTAL	900	100.0	100.0

5.17 Conspicuity

The pre-crash conspicuity of the motorcycle was evaluated along the pre-crash line-of-sight of the driver of the other vehicle, for the ambient light and background conditions. For examples of the category labels, "outstanding" would be characterized by the motorcycle headlamp on (within the 11 to 1 o'clock sector), color contrast for the fairing or upper torso garment, contrast with the background, ambient light falling on the sighted surfaces; "inconspicuous" would be characterized by no headlamp on, no color contrast for fairing or upper torso garment, no contrast with the background surfaces. A police motorcycle with headlamp on and red lights flashing could be "outstanding" and a small motorcycle, headlamp off, rider wearing a surplus army jacket, in the shade, could be "inconspicuous". Table 5.17.1 shows a compilation of those conspicuity evaluations for the motorcycle, and the other vehicle involved in the accident.

TABLE 5.17.1. PRE-CRASH CONSPICUITY (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Motorcycle				
Outstanding	1.	34	3.8	5.0
Average	2.	334	37.1	49.0
Low Conspicuity	3.	281	31.2	41.3
Inconspicuous	4.	32	3.6	4.7
Not Observed	8.	5	0.6	Missing
Not Applicable	9.	214	23.8	Missing
	TOTAL	900	100.0	100.0
Other Vehicle				
Outstanding	1.	239	26.6	34.7
Average	2.	413	45.9	60.0
Low Conspicuity	3.	31	3.4	4.5
Inconspicuous	4.	5	0.6	0.7
Not Observed	8.	5	0.6	Missing
Not Applicable	9.	207	23.0	Missing
	TOTAL	900	100.0	100.0

Only the contrast aspect of conspicuity was evaluated because the immediate precrash conditions eliminate the angular motion aspect. Thus, the evaluations of conspicuity in Table 5.17.1 relate only the contrast of the rider-motorcycle configuration with the ambient light and background. No relative motion within that ambient field is considered as contributing to the conspicuity evaluation.

The motorcycle conspicuity in pre-crash conditions was low, or was completely inconspicuous in 46.0% of those accidents where conspicuity was critical, e.g., other vehicle violation of the motorcycle right-of-way.

The conspicuity problem for motorcycles in traffic is in some ways simple and in other ways very complex. For example, only two of the accident involved motorcycle riders were wearing high visibility upper torso garments, e.g., a bright yellow Yamaha jacket. One of the riders was alcohol-involved and the other was driving in an obscure location traffic. On the other hand, the more typical rider with a low level of conspicuity would be wearing an army surplus, olive-drab jacket, the unintentional but effective camouflage.

Table 5.17.2 shows the use of very high or very low visibility upper torso garments by the motorcycle rider. The high visibility yellow or orange jacket was encountered 0.2% of those cases but the low visibility army surplus olive drab jacket was encountered 3.6% of those cases.

TABLE 5.17.2. MOTORCYCLE RIDER HI/LO VISIBILITY UPPER TORSO GARMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Not Remarkable	1.	854	94.9	96.2
Very High Contrast	2.	2	0.2	0.2
Very Low Contrast	3.	32	3.6	3.6
Unknown	8.	12	1.3	Missing
	TOTAL	900	100.0	100.0

The complexity of the conspicuity problem is illustrated by those cases where the motorcycle conspicuity was average, or outstanding. Such a case could be a law enforcement motorcycle in pursuit of a traffic violator. The motorcycle has the headlamp and flashing red lights on, and is slowed to approximately 35 mph going through an intersection. Just past the intersection, an automobile driver pulls out from a driveway into the path of the motorcycle. The motorcycle rider says "the automobile driver looked right at me and I thought we had eye contact". The automobile driver was not alcohol involved or otherwise impaired, or aggressively oriented. Similar situations appeared so often in the data collection that it is clear that high contrast conspicuity alone will not guarantee detection by the automobile driver. The motorcycle rider must not accept apparent eye contact as some significant communication, relating that the automobile driver has detected his presence in traffic.

The motorcycle conspicuity problem is serious. The violation of the motorcycle right-of-way by the other vehicle accounted for 64.7% of the multiple vehicle accidents. The failure of the other driver to "see" the motorcycle is the overwhelming part of these accidents. Any malicious and deliberate action of the other driver to "attack" the motorcycle rider is negligible in comparison to those fundamental detection failures; only two

of the 900 on-scene, in-depth cases involved an aggressive, malicious attack on the motorcycle rider and both were husband-wife disputes.

The contribution of the headlamp-on in daytime is described in detail in sections 6.11 and 114.

6.0 VEHICLE FACTORS

This section of the accident data shows the factors related to the vehicle involved in the accident. The motorcycle and automobile were examined for all mechanical factors related to the precrash and crash events. Of course, the motorcycle was correctly identified for type, size, manufacturer, modifications, etc., then examined for precrash and crash damage. The collision damage to the motorcycle and automobile, and the trajectories of the vehicles and occupants allowed the accident to be completely reconstructed so that collision contacts were defined, precrash lines-of-sight were analyzed, and precrash and crash speeds were determined. All mechanical elements were evaluated so that the effects of vehicle components and modifications could be determined; did crash bars help, did side stands ground out, did tire failure contribute to accident causation, where are the hazards, etc.?

6.1 Motorcycle Size and Type

Table 6.1.1 shows the motorcycle engine displacement for the 900 on-scene, in-depth (OSID) accident investigation cases. Table 6.1.2 shows the motorcycle engine displacement for the 3600 cases analyzed from police traffic accident reports (TAR). The motorcycle engine displacements were not noted in a large number of the traffic accident report cases (>40%) because that element was not required data on any law enforcement jurisdiction report form. Also, most police traffic accident investigators are not particularly familiar with motorcycle equipment, unless they happen to be motorcyclists themselves.

Table 6.1.3 shows the motorcycle engine displacement for the 54 fatal accidents of the 900 on-scene, in-depth accident investigations. Note that the large motorcycles (750cc and above) represent approximately one-third of all the accidents but are involved in approximately one-half of these fatal accidents.

Table 6.1.4 shows the motorcycle type for the 900 on-scene, in-depth accident cases, and those fatal accidents in that group (54). Of course, the majority of those motorcycles are conventional street motorcycles, essentially as manufactured but often with minor modifications. Genuine off-road motorcycles (dirt bikes) are not street legal because they are not equipped with lights, license, horn, muffler, street tires, etc., but they do participate in traffic accidents. Enduro, or dual purpose design motorcycles, encountered in these accidents were being used mainly as street bikes. The semi-chopper was the motorcycle modified with extended front forks, pull-back handlebars, and perhaps custom seat and "Harley" rear wheel. The semi-chopper and chopper were distinguished because of the potential for different collision avoidance handling or crashworthiness characteristics. Cafe racers were noted separately also because of these same differences.

Table 6.1.5 shows the engine type and number of cylinders for the motorcycles in the 900 on-scene, in-depth accident cases. Of course, no similar information was available from the traffic accident reports.

One particular feature available from all of the accident cases analyzed from the 3600 traffic accident reports was the distinction of the motorcycle rider and owner. Table 6.1.6 shows that 21.8% of the motorcycles were being ridden by a

TABLE 6.1.1. MOTORCYCLE MODEL SIZE OR ENGINE DISPLACEMENT (OSIDSs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Engine Displacement, cc.	49.	3	0.3	0.3	0.3
	50.	12	1.3	1.3	1.7
	60.	3	0.3	0.3	2.0
	70.	7	0.8	0.8	2.8
	73.	1	0.1	0.1	2.9
	75.	3	0.3	0.3	3.2
	80.	7	0.8	0.8	4.0
	83.	1	0.1	0.1	4.1
	90.	22	2.4	2.4	6.6
	100.	24	2.7	2.7	9.2
	120.	1	0.1	0.1	9.3
	125.	35	3.9	3.9	13.2
	127.	1	0.1	0.1	13.3
	150.	4	0.4	0.4	13.8
	160.	2	0.2	0.2	14.0
	175.	31	3.4	3.4	17.5
	180.	1	0.1	0.1	17.6
	185.	2	0.2	0.2	17.8
	200.	10	1.1	1.1	18.9
	250.	33	3.7	3.7	22.6
	305.	11	1.2	1.2	23.8
	350.	127	14.1	14.1	37.9
	360.	37	4.1	4.1	42.0
	380.	7	0.8	0.8	42.8
	400.	52	5.8	5.8	48.6
	450.	31	3.4	3.4	52.1
	500.	62	6.9	6.9	59.0
	550.	38	4.2	4.2	63.2
	600.	4	0.4	0.4	63.6
	650.	29	3.2	3.2	66.9
	750.	157	17.4	17.5	84.3
	800.	1	0.1	0.1	84.4
	850.	9	1.0	1.0	85.4
	900.	33	3.7	3.7	89.1
	1000.	31	3.4	3.4	92.5
	1200.	67	7.4	7.5	100.0
Unknown	9998.	1	0.1	Missing	
	TOTAL	900	100.0	100.0	

TABLE 6.1.2. MOTORCYCLE MODEL SIZE OR ENGINE DISPLACEMENT (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Engine Displacement, cc.	40.	1	0.0	0.0	0.0
	50.	12	0.3	0.6	0.6
	60.	3	0.1	0.1	0.7
	65.	1	0.0	0.0	0.8
	70.	16	0.4	0.7	1.5
	72.	1	0.0	0.0	1.6
	73.	1	0.0	0.0	1.6
	74.	1	0.0	0.0	1.7
	75.	7	0.2	0.3	2.0
	80.	17	0.5	0.8	2.8
	90.	54	1.5	2.5	5.3
	100.	58	1.6	2.7	8.0
	120.	2	0.1	0.1	8.1
	125.	102	2.8	4.8	12.9
	150.	5	0.1	0.2	13.1
	160.	5	0.1	0.2	13.4
	165.	1	0.0	0.0	13.4
	170.	1	0.0	0.0	13.5
	175.	98	2.7	4.6	18.0
	180.	3	0.1	0.1	18.2
	185.	10	0.3	0.5	18.6
	190.	1	0.0	0.0	18.7
	200.	20	0.6	0.9	19.6
	210.	1	0.0	0.0	19.7
	220.	6	0.2	0.3	19.9
	250.	109	3.0	5.1	25.0
	300.	4	0.1	0.2	25.2
	305.	21	0.6	1.0	25.2
	350.	414	11.5	19.3	45.5
	360.	95	2.6	4.4	50.0
	380.	6	0.2	0.3	50.3
	400.	123	3.4	5.7	56.0
	450.	88	2.4	4.1	60.1
	500.	114	3.2	5.3	65.4
	550.	82	2.3	3.8	69.3
	600.	3	0.1	0.1	69.4
	650.	65	1.8	3.0	72.4
	750.	384	10.7	17.9	90.4
	755.	1	0.0	0.0	90.4
	850.	27	0.7	1.3	91.7
	860.	1	0.0	0.0	91.7
	866.	1	0.0	0.0	91.8
	900.	68	1.9	3.2	95.0
	1000.	45	1.2	2.1	97.1
	1200.	61	1.7	2.8	99.9
	1600.	1	0.0	0.0	100.0
	2400.	1	0.0	0.0	100.0
Unknown	9998.	1459	40.5	Missing	
	TOTAL	3600	100.0	100.0	

TABLE 6.1.3. MOTORCYCLE MODEL SIZE OR ENGINE DISPLACEMENT (FATAL OSIDs ONLY)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Engine Displacement, cc.	80.	1	1.9	1.9	1.9
	90.	1	1.9	1.9	3.7
	125.	3	5.6	5.6	9.3
	250.	1	1.9	1.9	11.1
	350.	4	7.4	7.4	18.5
	360.	4	7.4	7.4	25.9
	380.	1	1.9	1.9	27.8
	400.	2	3.7	3.7	31.5
	450.	2	3.7	3.7	35.2
	500.	5	9.3	9.3	44.4
	550.	2	3.7	3.7	48.1
	650.	1	1.9	1.9	50.0
	750.	17	31.5	31.5	81.5
	900.	1	1.9	1.9	83.3
	1000.	2	3.7	3.7	87.0
	1200.	7	13.0	13.0	100.0
	TOTAL	54	100.0	100.0	100.0

TABLE 6.1.4. TYPE OF MOTORCYCLE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
<u>All OSIDs</u>			
Street OEM*	1.	623	69.2
Dirt Bike	2.	14	1.6
Enduro	3.	100	11.1
Semi-Chopper	4.	64	7.1
Chopper	5.	49	5.4
Cafe Racer	6.	28	3.1
Other	8.	22	2.4
	TOTAL	900	100.0
<u>Fatal OSIDs</u>			
Street OEM*	1.	36	66.7
Dirt Bike	2.	2	3.7
Enduro	3.	6	11.1
Semi-Chopper	4.	4	7.4
Chopper	5.	3	5.6
Cafe Racer	6.	3	5.6
	TOTAL	54	100.0

*OEM refers to Original Equipment Manufacture

TABLE 6.1.5. MOTORCYCLE ENGINE CHARACTERISTICS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Number of Cylinders				
One	1.	180	20.0	20.0
Two	2.	424	47.1	47.2
Three	3.	33	3.7	3.7
Four	4.	262	29.1	29.1
Unknown	8.	1	0.1	Missing
	TOTAL	900	100.0	100.0
Type of Engine				
4-cycle	1.	722	80.2	80.2
2-cycle	2.	178	19.8	19.8
	TOTAL	900	100.0	100.0

TABLE 6.1.6. MOTORCYCLE RIDER SURNAME SAME AS OWNER (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Yes	1.	2642	73.4	78.2
No	2.	736	20.4	21.8
Unknown	8.	222	6.2	Missing
	TOTAL	3600	100.0	100.0

person with a surname different from the registered owner. A special investigation of the cases showed that at least half of these cases were delays in the legal change of ownership. The other half was attributable to a variety of reasons with stolen motorcycles representing less than half a percent of those accident cases.

6.2 Manufacturer of the Accident-Involved Motorcycle

Table 6.2.1 shows the manufacturer of the motorcycles for the 900 on-scene, in-depth cases.

Table 6.2.2 shows the manufacturer of the motorcycles for the 3600 cases analyzed from police traffic accident reports.

In general, the distributions in these two sets of data agree.

TABLE 6.2.1. MOTORCYCLE MANUFACTURER (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
BMW	3.	14	1.6	1.6
BSA	4.	8	0.9	0.9
Bultaco	6.	1	0.1	0.1
CZ	8.	2	0.2	0.2
CAT-HPE	9.	1	0.1	0.1
Ducati	14.	2	0.2	0.2
Harley-Davidson	20.	95	10.6	10.6
Honda	23.	501	55.7	55.7
Indian	25.	1	0.1	0.1
Jawa	26.	3	0.3	0.3
Kawasaki	28.	73	8.1	8.1
Moto Guzzi	35.	7	0.8	0.8
Norton	40.	6	0.7	0.7
Puch	44.	1	0.1	0.1
Riverside	46.	1	0.1	0.1
Sachs	50.	2	0.2	0.2
Sears-Allstate	51.	1	0.1	0.1
Suzuki	54.	40	4.4	4.4
Triumph	55.	18	2.0	2.0
Vespa	60.	7	0.8	0.8
Yamaha	62.	110	12.2	12.2
Others	65.	6	0.7	0.7
	TOTAL	900	100.0	100.0

Table 6.2.3 shows the manufacturer of the motorcycles involved in the 54 fatal accident cases studied. Of course, those manufacturers of those more numerous or larger displacement motorcycles show the higher representation.

6.3 Year of Manufacture, or Model Year

Table 6.3.1 shows the year of manufacture, or equivalent model year, for the 900 on-scene, in-depth accident investigation cases.

Table 6.3.2 shows the year of manufacture, or equivalent model year, for the 3600 police traffic accident report cases.

6.4 Predominating Color of the Motorcycle

Table 6.4.1 shows the motorcycle colors from the 900 in-depth accident investigation cases.

Table 6.4.2 shows the same information collected from the analysis of the 3600 police traffic accident reports.

TABLE 6.2.2. MOTORCYCLE MANUFACTURER (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
BMW	3.	45	1.2	1.3
BSA	4.	26	0.7	0.7
Bridgestone	5.	1	0.0	0.0
Bultaco	6.	4	0.1	0.1
Benelli	7.	3	0.1	0.1
CZ	8.	2	0.1	0.1
Cushman	11.	9	0.2	0.3
Ducati	14.	5	0.1	0.1
Eagle	15.	1	0.0	0.0
Gemini	17.	1	0.0	0.0
Harley-Davidson	20.	321	8.9	9.1
Hodaka	22.	4	0.1	0.1
Honda	23.	1872	52.0	53.0
Indian	25.	7	0.2	0.2
Jawa	26.	8	0.2	0.2
KTM	27.	2	0.1	0.1
Kawasaki	28.	329	9.1	9.3
Moto Guzzi	35.	39	1.1	1.1
Norton	40.	30	0.8	0.8
Rickman	45.	1	0.0	0.0
Riverside	46.	1	0.0	0.0
Sachs	50.	1	0.0	0.0
Suzuki	54.	155	4.3	4.4
Triumph	55.	122	3.4	3.5
Vespa	60.	18	0.5	0.5
Yamaha	62.	482	13.4	13.7
Zundapp	64.	1	0.0	0.0
Other	65.	41	1.1	1.2
Unknown	98.	69	1.9	Missing
	TOTAL	3600	100.0	100.0

TABLE 6.2.3. MOTORCYCLE MANUFACTURER (OSID FATALS)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
BMW	3.	2	3.7	3.7
Harley-Davidson	20.	8	14.8	14.8
Honda	23.	31	57.4	57.4
Indian	25.	1	1.9	1.9
Kawasaki	28.	2	3.7	3.7
Suzuki	54.	2	3.7	3.7
Triumph	55.	1	1.9	1.9
Yamaha	62.	7	13.0	13.0
	TOTAL	54	100.0	100.0

TABLE 6.3.1. MOTORCYCLE YEAR OF MANUFACTURE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Year, 19__	37.	2	0.2	0.2
	40.	1	0.1	0.1
	47.	3	0.3	0.3
	48.	2	0.2	0.2
	49.	1	0.1	0.1
	51.	2	0.2	0.2
	52.	3	0.3	0.3
	56.	1	0.1	0.1
	58.	3	0.3	0.3
	59.	2	0.2	0.2
	60.	2	0.2	0.2
	62.	2	0.2	0.2
	63.	4	0.4	0.5
	64.	5	0.6	0.6
	65.	11	1.2	1.2
	66.	17	1.9	1.9
	67.	14	1.6	1.6
	68.	21	2.3	2.4
	69.	35	3.9	3.9
	70.	56	6.2	6.3
	71.	80	8.9	9.0
	72.	112	12.4	12.6
	73.	93	10.3	10.5
	74.	110	12.2	12.4
	75	157	17.4	17.7
	76.	96	10.7	10.8
	77.	49	5.4	5.5
	78.	3	0.3	0.3
Unknown	98.	13	1.4	Missing
	TOTAL	900	100.0	100.0

TABLE 6.3.2. MOTORCYCLE YEAR OF MANUFACTURE (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Year, 19___	27.	1	0.0	0.0
	37.	1	0.0	0.0
	39.	1	0.0	0.0
	40.	1	0.0	0.0
	41.	3	0.1	0.1
	42.	2	0.1	0.1
	45.	1	0.0	0.0
	46.	4	0.1	0.1
	47.	4	0.1	0.1
	48.	4	0.1	0.1
	49.	4	0.1	0.1
	50.	6	0.2	0.2
	51.	4	0.1	0.1
	52.	5	0.1	0.1
	53.	1	0.0	0.0
	54.	3	0.1	0.1
	55.	4	0.1	0.1
	56.	9	0.2	0.3
	57.	6	0.2	0.2
	58.	5	0.1	0.1
	59.	9	0.2	0.3
	60.	7	0.2	0.2
	61.	11	0.3	0.3
	62.	6	0.2	0.2
	63.	12	0.3	0.3
	64.	26	0.7	0.7
	65.	35	1.0	1.0
	66.	57	1.6	1.6
	67.	65	1.8	1.9
	68.	83	2.3	2.4
	69.	150	4.2	4.3
	70.	246	6.8	7.1
	71.	316	8.8	9.1
	72.	387	10.7	11.1
	73.	425	11.8	12.2
	74.	417	11.6	12.0
	75.	694	19.3	20.0
	76.	377	10.5	10.8
	77.	83	2.3	2.4
Unknown	98.	125	3.5	Missing
	TOTAL	3600	100.0	100.0

TABLE 6.4.1. MOTORCYCLE PREDOMINATING COLOR (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
White	1.	44	4.9	4.9
Yellow	2.	44	4.9	4.9
Orange	3.	93	10.3	10.4
Black	4.	109	12.1	12.1
Brown	5.	70	7.8	7.8
Blue	6.	163	18.1	18.2
Red	7.	199	22.1	22.2
Purple	8.	32	3.6	3.6
Green	9.	66	7.3	7.3
Silver	10.	23	2.6	2.6
Gold	11.	42	4.7	4.7
Metal Flake/Chrome	12.	3	0.3	0.3
Other	13.	10	1.1	1.1
Unknown	98.	2	0.2	Missing
	TOTAL	900	100.0	100.0

TABLE 6.4.2. MOTORCYCLE PREDOMINATING COLOR (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
White	1.	93	2.6	2.8
Yellow	2.	168	4.7	5.0
Orange	3.	259	7.2	7.8
Black	4.	563	15.6	16.9
Brown	5.	223	6.2	6.7
Blue	6.	577	16.0	17.3
Red	7.	746	20.7	22.4
Purple	8.	73	2.0	2.2
Green	9.	295	8.2	8.8
Silver	10.	37	1.0	1.1
Grey	11.	62	1.7	1.9
Gold	12.	145	4.0	4.3
Chrome-Metal Flake	13.	2	0.1	0.1
Others	14.	93	2.6	2.8
Unknown	98.	264	7.3	Missing
	TOTAL	3600	100.0	100.0

The data relate that the darker colors are present in accidents; the sum of black, blue, brown, purple, and green represent at least half of the motorcycles.

6.5 Collision Contact on the Motorcycle

Figure 6.5.1 shows the collision contact points for the 900 on-scene, in-depth accident cases. Because of the configuration of the typical motorcycle, there is a tendency for the collision contact to be located at the front wheel, fender, and forks. In 30.5% of those cases, the collision contact was at the very front tire and wheel, and another 31.4% (16.7 + 14.7) were at the right or left front of motorcycle. So the motorcycle accident has a collision contact configuration that is predominately frontal impact, 61.9% of all cases.

The initial collision contacts have a central side orientation in 31.9% of the collision cases (17.7 + 14.2).

Collision contact at the back of the motorcycle occurs in only 2.6% of those cases, and when the right and left back sides are included (1.5 + 2.1), the total involvement is only 6.2% of the accident cases. This low frequency of rear impacts is far below that of other types of motor vehicles and represents a low threat.

The higher involvement of the left side collision contact is due to the dominant accident configuration of the oncoming other vehicle turning left in front of the motorcycle.

6.6 Motorcycle Modifications

There were modifications to the motorcycles in the 900 on-scene, in-depth accident investigation cases as follows:

8.9% had extended fork tubes, 1.3% had extensions with slugs.
8.2% had accessories, e.g., radios, tape, stereo, etc.
6.3% had saddlebags.
16.6% had luggage box or boot.
30.1% had modified exhaust systems.
4.1% had modified front wheel and tire.
19.9% had modified rear wheel and tire.
13.0% had modified rear suspension.
18.1% had elevated foot rests or highway pegs.
6.1% had modified triple clamps.
5.6% had frame modifications.
18.1% had crashbars.
27.1% had sissybars (but sissybars had no significant injury association)
24.8% had modified seats.
6.1% had modified gas tanks.
12.0% had windshields (with or without fairings)
2.4% had frame-mounted fairings.
6.3% had steering-mounted fairings.
Only one motorcycle was equipped with a sidecar.

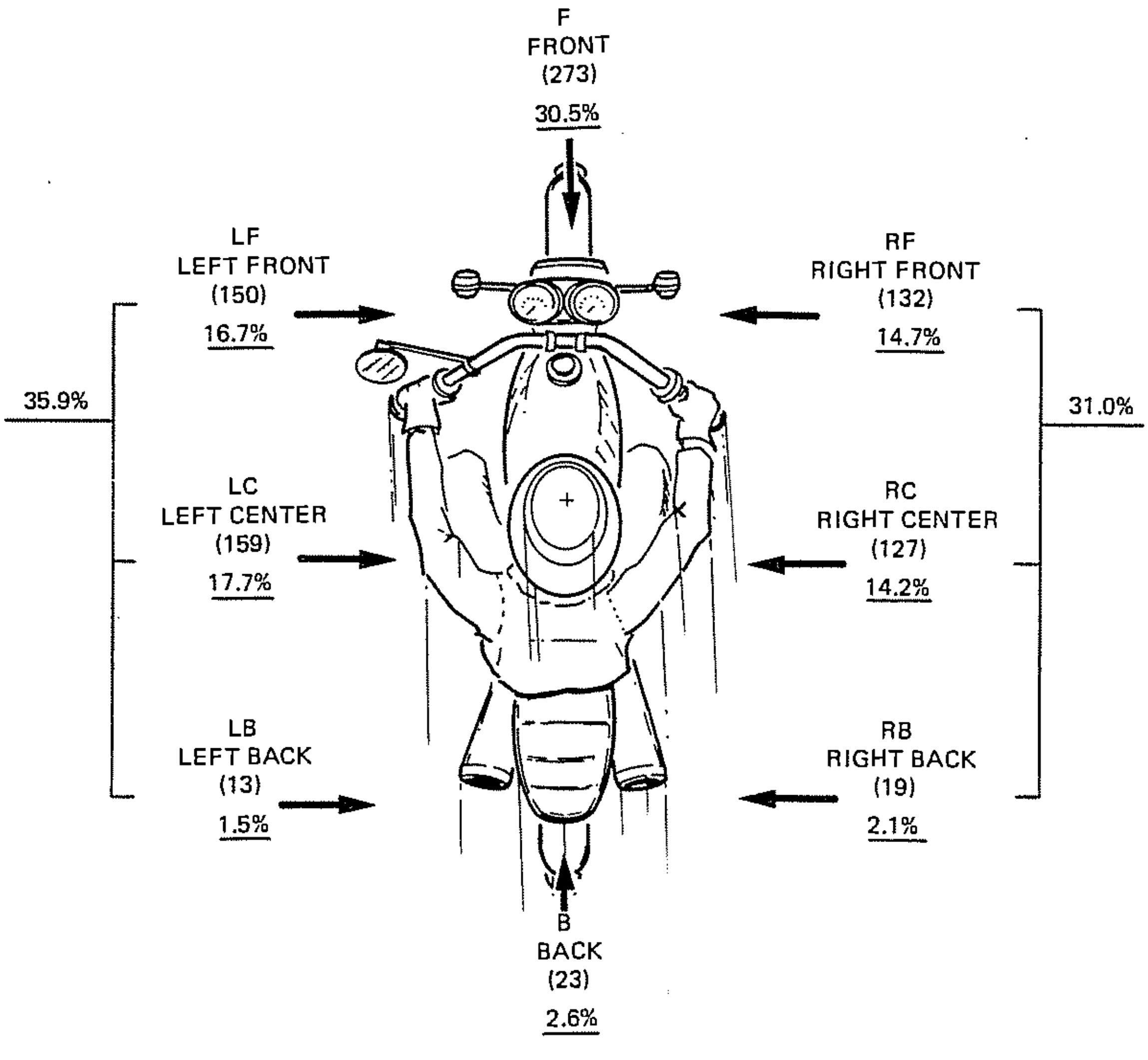


FIGURE 6.5.1. COLLISION CONTACT POINTS (OSIDs)

6.7 Fuel System Crashworthiness

Fuel Spills

Fuel spills (high flow stream) were present in 17.1% of the 900 on-scene, in-depth accident investigations; fuel leaks (low intermittent flow) occurred in 44.7% of the accidents. The total of 61.9% significant fuel spills or leaks represents a post-crash fire hazard far beyond the accident experience of other types or road vehicles. It is a typical post-crash posture of the motorcycle to be lying down on one side, far from the normal containment orientation of the fuel system. Consequently it is expected that some sort of fuel loss will occur.

The source of fuel spills and leaks is shown in Table 6.7.1. The fuel tank cap and carburetor vents dominate as a source of fuel spills and leaks. The motorcycle post-crash point of rest is reliably distinguished by the spill spots from the tank cap and carburetors. Also, the post-crash orientation of the motorcycle and movement in vehicle recovery can be distinguished in most accident cases where fuel spills occur.

TABLE 6.7.1. FUEL LEAKAGE/SPILLAGE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Fuel Spillage				
Yes	1.	149	16.6	17.1
No	2.	720	80.0	82.9
Unknown	8.	31	3.4	Missing
	TOTAL	900	100.0	100.0
Fuel Leakage				
Yes	1.	385	42.8	44.7
No	2.	477	53.0	55.3
Unknown	8.	38	4.2	Missing
	TOTAL	900	100.0	100.0
Source of Fuel Spill or Leak				
Tank	1.	347	38.6	71.1
Fuel Lines	2.	36	4.0	7.4
Fuel Filter	3.	1	0.1	0.2
Carburetor	4.	104	11.6	21.3
Unknown	8.	55	6.1	Missing
N.A.	9.	357	39.7	Missing
	TOTAL	900	100.0	100.0

Fuel Tank Crashworthiness

Retention: Table 6.7.2 shows that 3.2% of the 900 accident cases involved partial separation of the fuel tank from the motorcycle; 2.1% of the accidents resulted in complete separation of the tank from the motorcycle.

Deformation: Table 6.7.2 also shows 45.4% of the 900 cases involved no deformation or damage to the fuel tank; 36.8% suffered mild deformation, 13.1% suffered moderate deformation, and 4.7% experienced severe deformation of the tank. Severe deformation of the tank would be characterized by at least 1/3 reduction of the tank volume, and a high potential for fuel loss.

TABLE 6.7.2. FUEL TANK STATUS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Tank Retention				
Complete	1.	850	84.4	94.7
Partial	2.	29	3.2	3.2
Total Separation	3.	19	2.1	2.1
Unknown	8.	2	0.2	Missing
	TOTAL	900	100.0	100.0
Tank Deformation				
None	0.	408	45.3	45.3
Mild	1.	331	36.8	36.8
Moderate	2.	118	13.1	13.1
Severe	3.	42	4.7	4.7
Unknown	8.	1	0.1	Missing
	TOTAL	900	100.0	100.0

Violation: Table 6.7.3 shows that 4.2% of the fuel tanks experienced intrusion or penetration of the tank volume so that a severe fuel loss would occur.

Tank Cap: Table 6.7.3 also shows that 3.7% of the fuel tank caps opened during the crash impact. The majority of those tank caps opening were forward-hinged flip-up type caps.

Fires

As shown in Table 6.7.4, crash fires occurred in 3 and post-crash fires occurred in 11 of the 900 on-scene, in-depth accident cases, i.e., 1.2% of the accidents. This frequency of fire occurence is low when compared with the high availability of fuel from spills and leaks (61.9% of the accidents). The fuel tank cap opening was the predominating fuel source in these fires, and such a

TABLE 6.7.3. FUEL TANK VIOLATION AND CAP SECURITY (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Tank Violation				
None	0.	861	95.7	95.8
Yes	1.	38	4.2	4.2
Unknown	8.	1	0.1	Missing
	TOTAL	900	100.0	100.0
Cap Remain Secured?				
Yes	1.	859	95.3	96.3
No	2.	33	3.7	3.7
Unknown	8.	8	0.9	Missing
	TOTAL	900	100.0	100.0

TABLE 6.7.4. FIRE OCCURRENCE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Did Precrash Fire Occur?				
No	2.	900	100.0	100.0
	TOTAL	900	100.0	100.0
Did Crash Fire Occur?				
Yes	1.	3	0.3	0.3
No	2.	897	99.7	99.7
	TOTAL	900	100.0	100.0
Did Postcrash Fire Occur or Crash Fire Continue?				
Yes	1.	11	1.2	1.2
No	2.	889	98.8	98.8
	TOTAL	900	100.0	100.0

source would provide a high volume of fuel when ignition sources are available. The fuel and ignition sources are shown in Table 6.7.5.

TABLE 6.7.5. FUEL/IGNITION SOURCES (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Fuel Source for Fire				
Tank Cap Separation	2.	9	1.0	81.8
Carburetor	3.	1	0.1	9.1
Petcock	5.	1	0.1	9.1
Not Applicable	9.	889	98.8	Missing
	TOTAL	900	100.0	100.0
Ignition Source				
Electrical System	1.	3	0.3	27.3
Exposed Exhaust	2.	1	0.1	9.1
Friction Sparks	3.	6	0.7	54.5
Other	4.	1	0.1	9.1
Not Applicable	9.	889	98.8	Missing
	TOTAL	900	100.0	100.0

The low occurrence of fires in the presence of high fuel availability (Table 6.7.1) is explained by the fact that the most common ignition source available is friction sparks from the sliding motorcycle. If the fuel concentration is low at the ignition source, there is no fire; if the fuel concentration is high only at the point of rest, the ignition source is depleted and there is no fire. As the motorcycle reaches the post-crash point of rest, the usual ignition sources are depleted and a low volume flow fuel source is not ignited.

6.8 Pre-Crash and Crash Speeds

Table 6.8.1 (Appendix C.2) shows the distribution of pre-crash speeds for the motorcycles involved in the 900 accident cases. The median speed is 29.8 miles per hour for all cases. The single and multiple vehicle collisions are presented separately.

Table 6.8.2 (Appendix C.2) shows the distributions of the crash speeds for the motorcycles in the 900 accident cases. The median speed is 21.5 miles per hour for all cases. The single and multiple precrash and crash speeds are summarized in Table 6.8.3, and these data show that the single vehicle accidents are characterized by generally more frequent high precrash and crash speeds.

TABLE 6.8.3. SUMMARY OF PRECRASH AND CRASH SPEEDS FOR SINGLE MULTIPLE VEHICLE COLLISIONS

Precrash Speeds	Single Vehicle Collisions (208)	Multiple Vehicle Collisions (661)	Unknown (31)
0-10 mph	17 (.082)	46 (.070)	2
11-20	23 (.111)	77 (.116)	4
21-30	47 (.226)	238 (.360)	12
31-40	42 (.202)	221 (.334)	6
41-50	36 (.173)	59 (.089)	5
51-60	22 (.106)	14 (.021)	2
61-70	14 (.067)	1 (0)	0
71-80	1 (.005)	0 (0)	0
>80	2 (.010)	0 (0)	0
Unknown	4 (.019)	5 (.007)	0
Crash Speeds			
0-10 mph	18 (.087)	62 (.094)	3
11-20	61 (.293)	273 (.413)	15
21-30	50 (.240)	215 (.325)	5
31-40	38 (.183)	85 (.129)	6
41-50	14 (.067)	17 (.026)	1
51-60	14 (.067)	9 (.014)	1
61-70	9 (.043)	0 (0)	0
71-80	2 (.010)	0 (0)	0
>80	0 (0)	0 (0)	0
Unknown	2 (.010)	0 (0)	0

Each of the 900 cases was completely reconstructed analytically and the vehicle dynamics defined to determine the pre-crash and crash speeds. Vehicle damage analysis, post-crash trajectories, and skid and scuff marks were used to determine these speeds. No similar information was available from examination of the 3600 police traffic accident reports.

The distribution of the pre-crash and crash speeds is shown in Figure 6.8.4. Note the median speeds of 29.8 and 21.5 miles per hour, and the one-in-a-thousand crash speed is approximately 86 miles per hour.

6.9 Contributory Tire Conditions

Table 6.9.1 shows the frequencies of contributory tire conditions for the front and rear tires of the accident involved motorcycles examined for the on-scene, in-depth data collection. The greatest part of accident causation by vehicle failure (2.8%) was tire failure, primarily by puncture flats. All of those tires involved were tube-type and the deflation was usually sudden, causing immediate control distress.

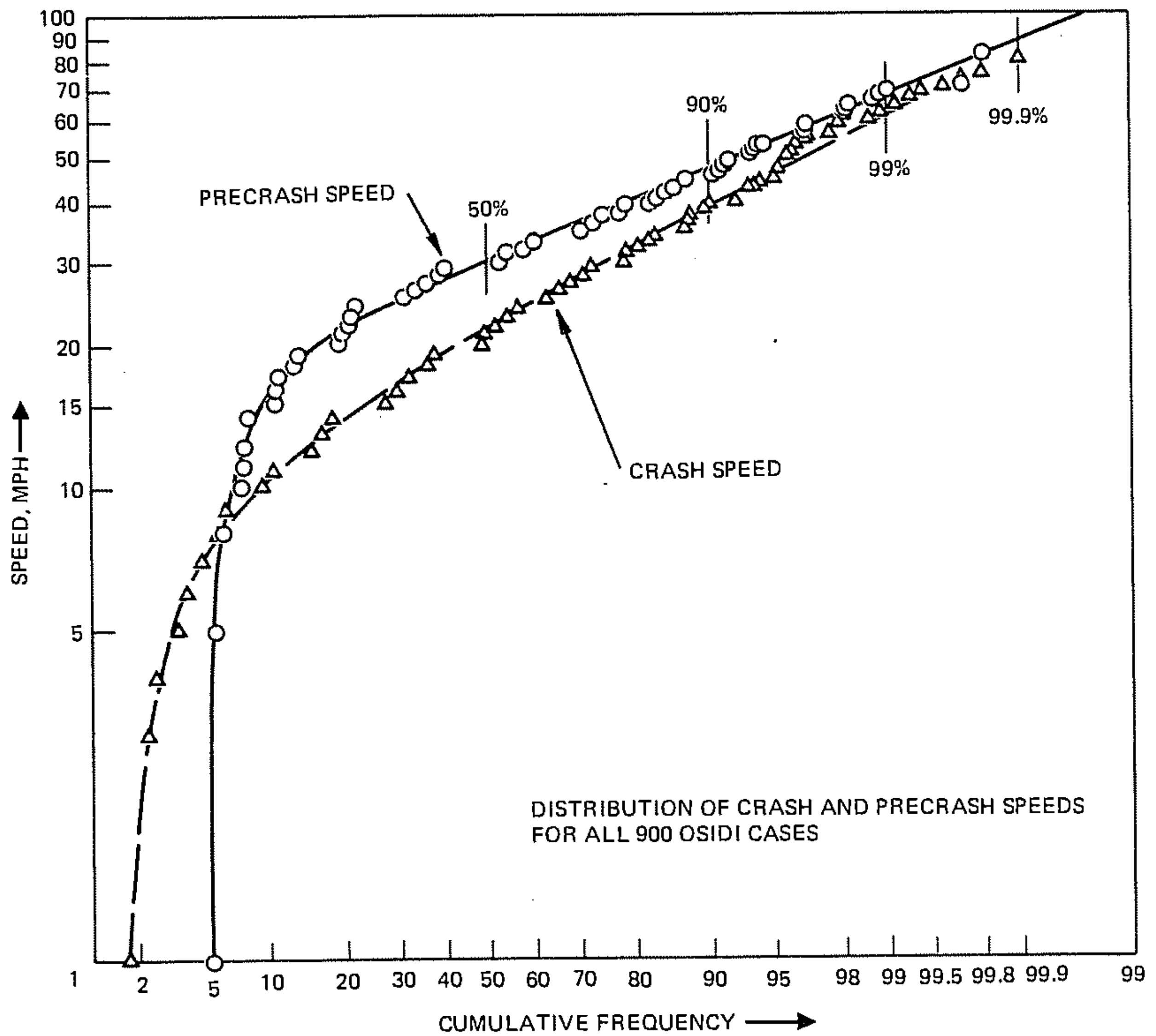


FIGURE 6.8.4. DISTRIBUTION OF CRASH AND PRECRASH SPEEDS FOR ALL 900 OSIDI CASES.

TABLE 6.9.1. CONTRIBUTORY TIRE CONDITIONS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Front Tire				
None	0.	859	95.4	95.6
Puncture Flat	1.	2	0.2	0.1
Worn Smooth	3.	4	0.4	0.4
Low Pressure	4.	23	2.6	2.6
High Pressure	5.	9	1.0	1.0
Others	7.	2	0.2	0.2
Unknown	8.	1	0.1	Missing
	TOTAL	900	100.0	100.0
Rear Tire				
None	0.	837	93.0	93.0
Puncture Flat	1.	12	1.3	1.2
Worn Smooth	3.	11	1.2	1.2
Low Pressure	4.	22	2.4	2.4
High Pressure	5.	12	1.3	1.3
Valve Failure	6.	1	0.1	0.1
Others	7.	5	0.6	0.6
	TOTAL	900	100.0	100.0

Dynamic tire failure was not involved in the majority of puncture flats. In the majority of cases, loss of control occurred before the tire bead unseated, or the tire bead did not unseat at all. As a result, there is no obvious requirement for complicated wheel design or bead retention devices. The dynamic tire failure problem is of minor importance when compared to the major accident and injury causation problems of conspicuity, rider error, head protection, etc.

Tires worn smooth contributed reduced traction with contaminated roadway and were accounted for only when that reduced traction was involved in the accident events.

Tires with pressures excessively high or low could reduce braking or cornering ability. When those pressures deviated more than 30% from standard pressures, and that hard or soft tire contributed to the accident involvement, those data were so noted. As an example, one accident studied involved a semi-chopper 750cc motorcycle with a front tire inflated to 58 psi. Front brake application during collision avoidance action resulted in premature front wheel lock-up, slide-out and fall. This result was made more likely by this hard, over-inflated tire.

Approximately 6% of those vehicles examined had tires in poor or marginal condition, but there was no direct contribution to accident causation since outright mechanical tire failure modes were not encountered.

Tables 6.9.2 (Appendix C.2) and 6.9.3 (Appendix C.2) illustrates the effect of the presence of a passenger on the contributory front and rear tire conditions. These data show the additional involvement of the passenger-carrying motorcycle experiencing puncture flat of the rear tire.

6.10 Cornering Clearance

Table 6.10.1 shows the frequencies of accident involved cornering clearance problems. The sidestand was involved more than any other component, and three of these cases involved failure to retract the sidestand after starting off and entering traffic. Each of these three cases involved a significant attention problem involving the motorcycle rider (passenger, traffic, alcohol involvement) and one case of an unhelmeted rider resulted in fatal injuries.

TABLE 6.10.1. CORNERING CLEARANCE IF ACCIDENT-INVOLVED

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
All OSIDs				
Sidestand	1.	9	1.0	32.1
Centerstand	2.	6	0.7	21.4
Foot Pegs	3.	6	0.7	21.4
Mufflers-Pipes	4.	2	0.2	7.1
Crash Bars	5.	2	0.2	7.1
Others	6.	3	0.3	10.7
Unknown	8.	1	0.1	Missing
Not Applicable	9.	871	96.8	Missing
	TOTAL	900	100.0	100.0
Fatal OSIDs				
Sidestand	1.	1	1.9	33.3
Foot Pegs	3.	1	1.9	33.3
Others	6.	1	1.9	33.3
Not Applicable	9.	51	94.4	Missing
	TOTAL	54	100.0	100.0

6.11 Pre-Crash Line-of-Sight

As a matter of the complete reconstruction of the accident dynamics, the pre-crash and crash speeds and directions were determined for the motorcycle and the other vehicle involved in each of the on-scene, in-depth accident cases. At that point in the accident events corresponding to the accident precipitating event, the line-of-sight from the motorcycle rider to the other vehicle was determinded and recorded as a "clock face" direction. For example, consider the motorcycle approaching an intersection and an automobile in opposing traffic just

beginning to turn left in front of the motorcycle. In this case, the typical pre-crash line-of-sight from the motorcycle to that automobile would be approximately "eleven o'clock". It is important to distinguish this pre-crash line-of-sight from vehicle paths, or any other element of the pre-crash or collision dynamics.

The pre-crash line-of-sight relates several factors important in accident prevention. The principal application is in the detection of hazards by the motorcycle rider. The search and detection priorities are defined by the distribution of these hazards around the motorcycle rider. Also, the reciprocal of each line-of-sight defines that part of the motorcycle exposed to view by the driver of the other vehicle. For example, if the pre-crash line-of-sight to the left turning automobile is "eleven o'clock" then that front left side of the motorcycle is that surface most related to motorcycle conspicuity in that particular accident.

Table 6.11.1 shows the distribution for the pre-crash lines-of-sight for the 900 on-scene, in-depth accident cases. There were 716 of these accidents which involved another vehicle (or pedestrian, animal, etc.) and 184 which were single vehicle accidents with nothing involved but the motorcyclist. Hence, no data were recorded for those 184 single vehicle collisions. A special feature of these data are the concentrations at 11, 12, and 1 o'clock pre-crash lines-of-sight, with the sum being 77.0%. The highest concentration is at 11 o'clock (43.4%); that pre-crash line-of-sight is characteristic of the automobile turning left in front of the oncoming motorcycle. The high concentrations of the 11, 12 and 1 o'clock positions illustrate the sensitivity of the accident situation to rider attention and the clear orientation to the motorcycle path. In other words, "motorcycle rider, watch where you are going; that is where at least three-fourths of the accidents are coming from!"

It is seen that the extreme peripheral fields are of little significance in hazard detection.

On rider's right,

At 3 o'clock, 0.8% of the hazards
4 o'clock, 0.4% of the hazards
5 o'clock, 0.8% of the hazards

On rider's left,

At 9 o'clock, 2.7% of the hazards
8 o'clock, 0.3% of the hazards
7 o'clock, 1.3% of the hazards

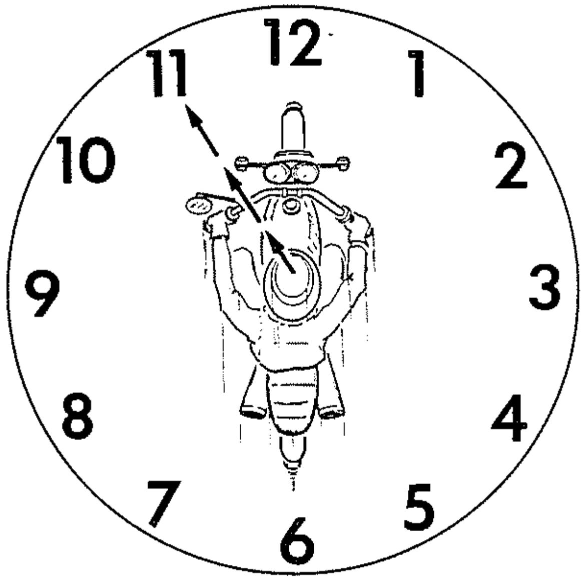
And, from directly behind the rider,

At 6 o'clock, 3.4% of the hazards

The extremely low incidence of hazards in the peripheral field denies the need for wide eye space in safety helmets; there is no need for lateral visual space greater than the current standard of 105° from the midsagittal plane.

TABLE 6.11.1. BEARING OF OTHER VEHICLES AS SEEN FROM MOTORCYCLE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
One o'clock	1.	120	13.3	16.8
Two o'clock	2.	43	4.8	6.0
Three o'clock	3.	6	0.7	0.8
Four o'clock	4.	3	0.3	0.4
Five o'clock	5.	6	0.7	0.8
Six o'clock	6.	24	2.7	3.4
Seven o'clock	7.	9	1.0	1.3
Eight o'clock	8.	2	0.2	0.3
Nine o'clock	9.	19	2.1	2.7
Ten o'clock	10.	53	5.9	7.4
Eleven o'clock	11.	311	34.6	43.4
Twelve o'clock	12.	120	13.3	16.8
N.A.	99.	184	20.4	Missing
	TOTAL	900	100.0	100.0



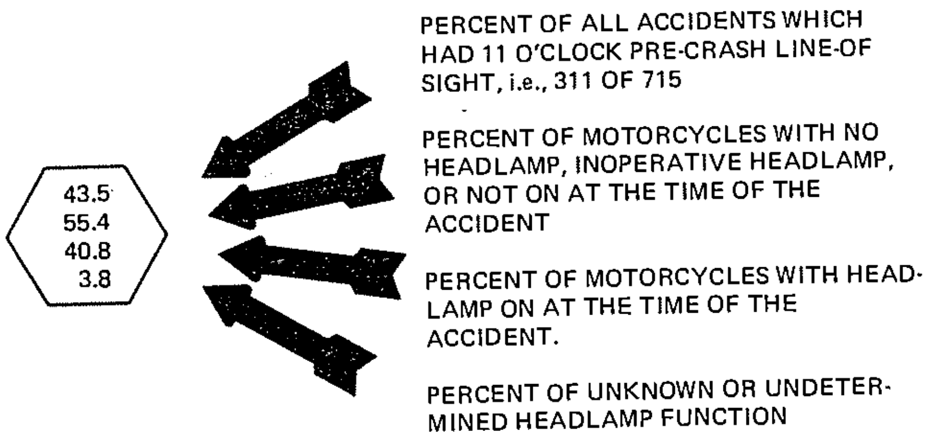
The sum of the 10, 11, 12, 1 and 2 o'clock precrash lines-of-sight is 90.4%. This clearly establishes the conspicuity problem of the motorcycle as one of the front surfaces. All conspicuity treatments should focus upon this frontal region of the motorcycle-rider configuration because this is the surface most often presented to the driver of the other vehicle.

The predominating pre-crash line-of-sight orientations of 11+12+1 o'clock relates the feeble contribution possible by side reflectors on motorcycles. The reflector orientation is ineffective and no light source from the other vehicle is directed at the reflector. Active sidelamps with the forward oblique - rather than lateral - alignment have the potential of effective conspicuity contribution. A good example of effective design for this favorable effect is the Vetter Wind-jammer fairing with "Leading Edge Lights."

Retroreflective material on the motorcycle has the same shortcoming as any reflectorized surface; the contribution to conspicuity is dependent upon the other vehicle light source aimed at that reflector on the motorcycle. This situation is absent in daytime and rare at nighttime. Of course, the retroreflective material will respond to ambient light but that source has obvious limits for daylight considerations.

Table 6.11.2 shows the distribution of the precrash lines-of-sight for the ambient light at the accident scene. Daytime and daylight predominate with 552 or 77.1% of those accidents. Dawn-dusk light conditions existed for 42 or 5.9% and 122 or 17.0% of those accidents occurred at night.

Table 6.11.3 shows the relationship between motorcycle headlamp equipment and function for the pre-crash line-of-sight for all of the multiple vehicle collisions (716) in the total of on-scene, in-depth accident investigations (900). Table 6.11.4 illustrates these data for all multiple vehicle accidents for all 24 hours of the day, i.e., daylight + dusk + dawn + night. The numbers collected at each clock position are as follows, (for example, at 11 o'clock):



Tables 6.11.5 and 6.11.6 show those pre-crash line-of-sight distributions for night conditions. In these data, the predominant orientation is the 11 o'clock position, which is most likely the oncoming automobile turning left in front of the motorcycle. Also, the total of 11, 12, and 1 o'clock pre-crash line-of-sight frequencies is 77.9% of all orientations.

The peripheral fields illustrate extremely low frequencies; the headlamp use is high, but the non-use of headlamp noted in the 11 and 12 o'clock positions is the simplest explanation for nighttime accident involvement. The 6.6% of precrash line-of-sight at 6 o'clock implies some need for more conspicuous rear lamps.

Tables 6.11.7 and 6.11.8 show these data for dusk-dawn ambient light conditions. The sum of the precrash line-of-sight frequencies for 11, 12, and 1 o'clock is 78.6%.

Tables 6.11.9 and 6.11.10 show those data for daylight conditions. The sum of the precrash line-of-sight frequencies for 11, 12, and 1 o'clock is 76.6% and the peripheral regions have only insignificant contribution. The most important

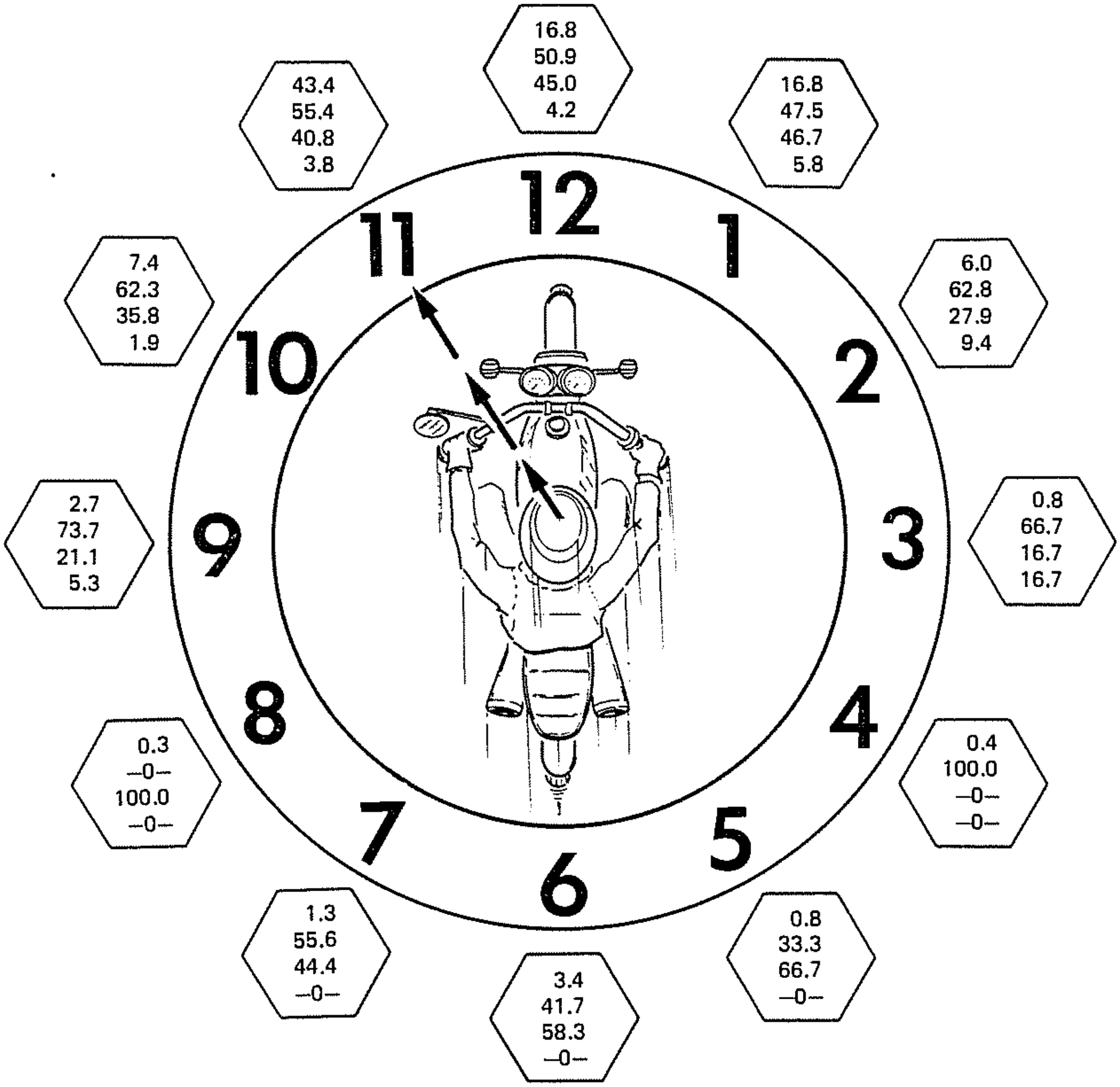
TABLE 6.11.2. BEARING OF OTHER VEHICLES AS SEEN FROM MOTORCYCLE VERSUS ILLUMINATION

Bearing of the Other Vehicle	Count Row Pct Col Pct Tot Pct	Illumination: Daylight	Dawn or Dusk	Night-Lighted	Night-Unlighted	Row Total
	1.	90 75.0 16.3 12.6	11 9.2 26.2 1.5	17 14.2 15.6 2.4	2 1.7 15.4 0.3	120 16.8
	2.	40 93.0 7.2 5.6	0 0.0 0.0 0.0	2 4.7 1.8 0.3	1 2.3 7.7 0.1	43 6.0
	3.	5 83.3 0.9 0.7	0 0.0 0.0 0.0	1 16.7 0.9 0.1	0 0.0 0.0 0.0	6 0.8
	4.	2 66.7 0.4 0.3	1 33.3 2.4 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 0.4
	5.	2 33.3 0.4 0.3	1 16.7 2.4 0.1	3 50.0 2.8 0.4	0 0.0 0.0 0.0	6 0.8
	6.	15 62.5 2.7 2.1	1 4.2 2.4 0.1	5 20.8 4.6 0.7	3 12.5 23.1 0.4	24 3.4
	7.	6 66.7 1.1 0.8	2 22.2 4.8 0.3	1 11.1 0.9 0.1	0 0.0 0.0 0.0	9 1.3
	8.	2 100.0 0.4 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.3
	9.	15 78.9 2.7 2.1	2 10.5 4.8 0.3	2 10.5 1.8 0.3	0 0.0 0.0 0.0	19 2.7
	10.	42 79.2 7.6 5.9	2 3.8 4.8 0.3	8 15.1 7.3 1.1	1 1.9 7.7 0.1	53 7.4
	11.	234 75.2 42.4 32.7	16 5.1 38.1 2.2	57 18.3 52.3 8.0	4 1.3 30.8 0.6	311 43.4
	12.	99 82.5 17.9 13.8	6 5.0 14.3 0.8	13 10.8 11.9 1.8	2 1.7 15.4 0.3	120 16.8
	Column Total	552 77.1	42 5.9	109 15.2	13 1.8	716 100.0

TABLE 6.11.3. BEARING OF OTHER VEHICLE AS SEEN FROM MOTORCYCLE VERSUS MOTORCYCLE HEADLAMP OPERATION (OSIDs)

Count Row Pct Col Pct Tot Pct	Motorcycle Headlamp Operation						
Bearing of the Other Vehicle	Not Equipped	Equip., Not Oper.	Oper. Not On	On At Accident	Equip., Not Known	Unknown If On	Row Total
1.	2 1.7 12.5 0.3	1 0.8 5.9 0.1	54 45.0 15.2 7.5	56 46.7 18.9 7.8	3 2.5 20.0 0.4	4 3.3 25.0 0.6	120 16.8
2.	3 7.0 18.8 0.4	1 2.3 5.9 0.1	23 53.5 6.5 3.2	12 27.9 4.0 1.7	2 4.7 13.3 0.3	2 4.7 12.5 0.3	43 6.0
3.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	4 66.7 1.1 0.6	1 16.7 0.3 0.1	1 16.7 6.7 0.1	0 0.0 0.0 0.0	6 0.8
4.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 100.0 0.8 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 0.4
5.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 33.3 0.6 0.3	4 66.7 1.3 0.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 0.8
6.	1 4.2 6.3 0.1	0 0.0 0.0 0.0	9 37.5 2.5 1.3	14 58.3 4.7 2.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	24 3.4
7.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 55.6 1.4 0.7	4 44.4 1.3 0.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	9 1.3
8.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 0.7 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.3
9.	0 0.0 0.0 0.0	1 5.3 5.9 0.1	13 68.4 3.7 1.8	4 21.1 1.3 0.6	1 5.3 6.7 0.1	0 0.0 0.0 0.0	19 2.7
10.	3 5.7 18.8 0.4	5 9.4 29.4 0.7	25 47.2 7.0 3.5	19 35.8 6.4 2.7	0 0.0 0.0 0.0	1 1.9 6.3 0.1	53 7.4
11.	7 2.3 43.8 1.0	7 2.3 41.2 1.0	158 50.8 44.5 22.1	127 40.8 42.8 17.7	6 1.9 40.0 0.8	6 1.9 37.5 0.8	311 43.4
12.	0 0.0 0.0 0.0	2 1.7 11.8 0.3	59 49.2 16.6 8.2	54 45.0 18.2 7.5	2 1.7 13.3 0.3	3 2.5 18.8 0.4	120 16.8
Column Total	16 2.2	17 2.4	355 49.6	297 41.5	15 2.1	16 2.2	716 100.0

TABLE 6.11.4. MOTORCYCLE RIDER PRE-CRASH LINE-OF-SIGHT TO THE OTHER VEHICLE



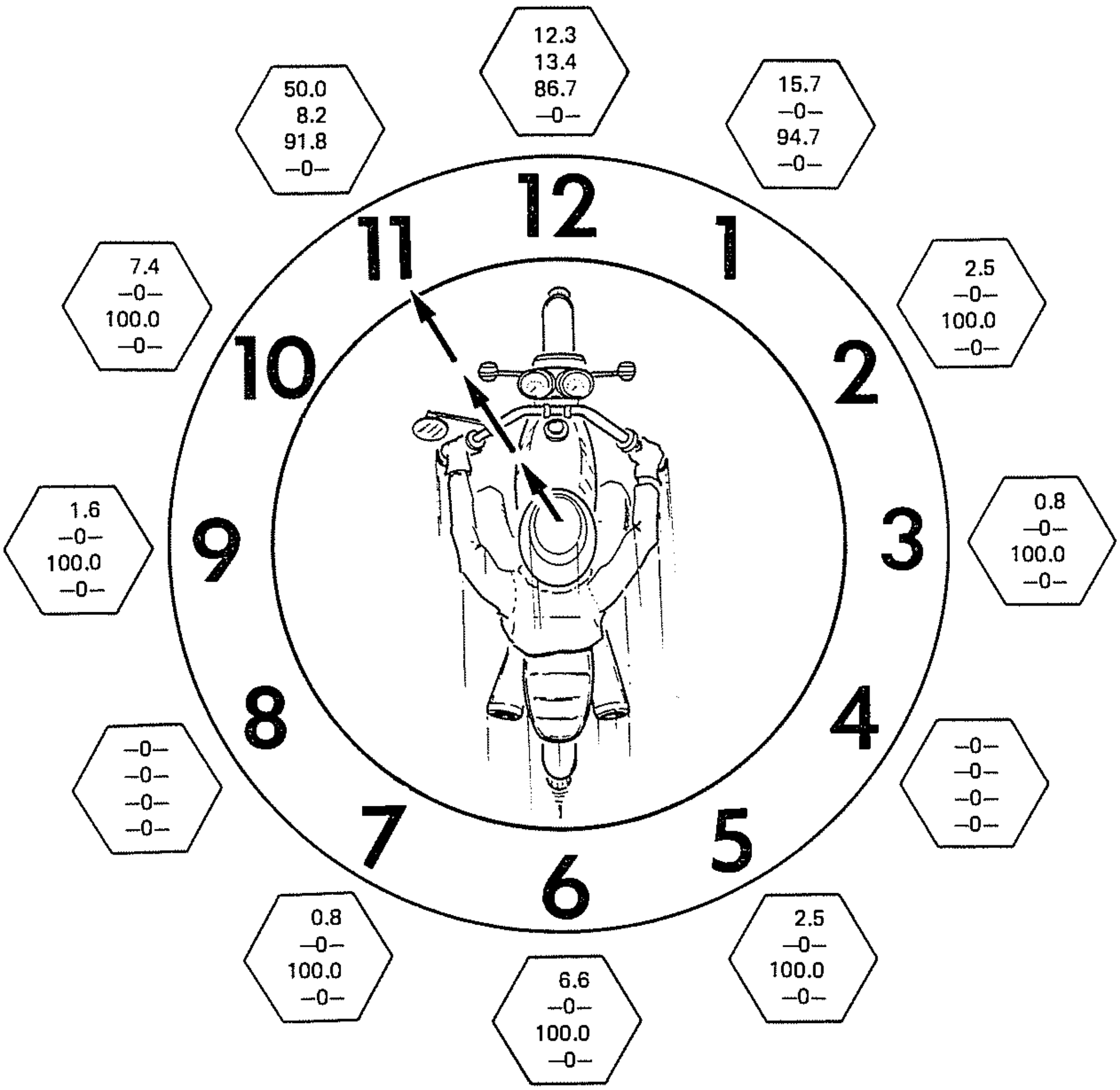
TOTAL: DAY + DUSK-DAWN + NIGHT (716)
24 HOURS
11 + 12 + 1: 77.0%

TABLE 6.11.5. BEARING OF OTHER VEHICLE AS SEEN FROM MOTORCYCLE VERSUS MOTORCYCLE HEADLAMP OPERATION

Count Row Pct Col Pct Tot Pct	Motorcycle Headlamp Operation					
Bearing of the Other Vehicle	Not Equipped	Equip., Not Oper	Oper, Not On	On At Accident	Equip., Not Known	Row Total
1.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	18 94.7 15.8 14.8	1 5.3 100.0 0.8	19 15.6
2.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 100.0 2.6 2.5	0 0.0 0.0 0.0	3 2.5
3.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 0.9 0.8	0 0.0 0.0 0.0	1 0.8
5.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 100.0 2.6 2.5	0 0.0 0.0 0.0	3 2.5
6.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	8 100.0 7.0 6.6	0 0.0 0.0 0.0	8 6.6
7.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 0.9 0.8	0 0.0 0.0 0.0	1 0.8
9.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 1.8 1.6	0 0.0 0.0 0.0	2 1.6
10.	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	9 100.0 7.9 7.4	0 0.0 0.0 0.0	9 7.4
11.	1 1.6 100.0 0.8	0 0.0 0.0 0.0	4 6.6 80.0 3.3	56 91.8 49.1 45.9	0 0.0 0.0 0.0	61 50.0
12.	0 0.0 0.0 0.0	1 6.7 100.0 0.8	1 6.7 20.0 0.8	13 86.7 11.4 10.7	0 0.0 0.0 0.0	15 12.3
Column Total	1 0.8	1 0.8	5 4.1	114 93.4	1 0.8	122 100.0

Night Only (122 cases), 11 + 12 + 1 o'clock: 77.9%

TABLE 6.11.6. MOTORCYCLE RIDER PRE-CRASH LINE-OF-SIGHT TO THE OTHER VEHICLE (OSIDs)



NIGHTTIME ONLY (122)
11 + 12 + 1: 77.9%

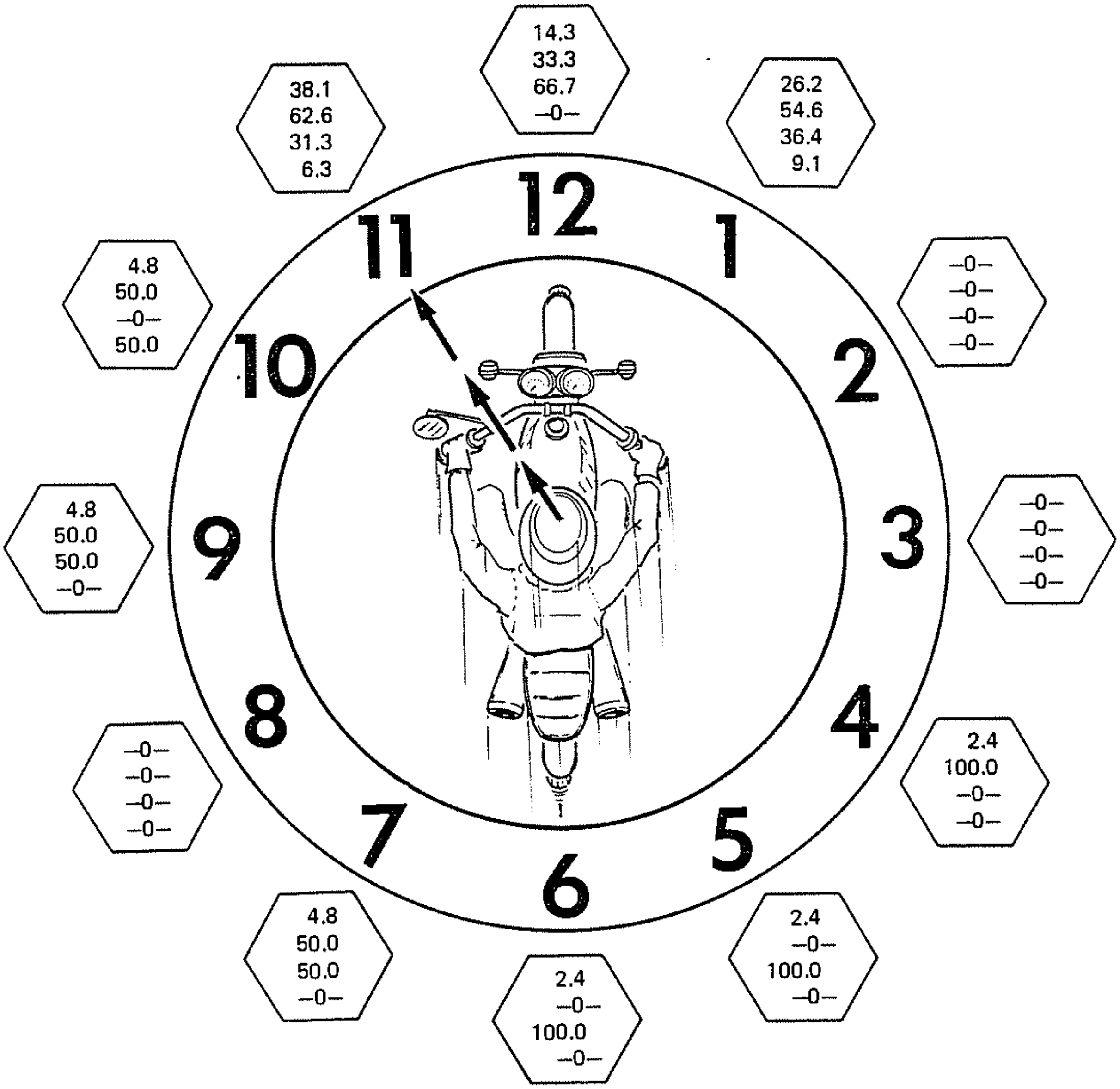
TABLE 6.11.7. BEARING OF OTHER VEHICLE AS SEEN FROM MOTORCYCLE VERSUS MOTORCYCLE HEADLAMP OPERATION

Bearing of the Other Vehicle	Count / Row Pct / Col Pct / Tot Pct	Motorcycle Headlamp Operation: Not Equipped	Equip., Not Oper	Oper, Not On	On at Accident	Unknown If On	Row Total
1.	Count	1	1	4	4	1	11
	Row Pct	9.1	9.1	36.4	36.4	9.1	26.2
	Col Pct	50.0	33.3	23.5	23.5	33.3	
	Tot Pct	2.4	2.4	9.5	9.5	2.4	
4.	Count	0	0	1	0	0	1
	Row Pct	0.0	0.0	100.0	0.0	0.0	2.4
	Col Pct	0.0	0.0	5.9	0.0	0.0	
	Tot Pct	0.0	0.0	2.4	0.0	0.0	
5.	Count	0	0	0	1	0	1
	Row Pct	0.0	0.0	0.0	100.0	0.0	2.4
	Col Pct	0.0	0.0	0.0	5.9	0.0	
	Tot Pct	0.0	0.0	0.0	2.4	0.0	
6.	Count	0	0	0	1	0	1
	Row Pct	0.0	0.0	0.0	100.0	0.0	2.4
	Col Pct	0.0	0.0	0.0	5.9	0.0	
	Tot Pct	0.0	0.0	0.0	2.4	0.0	
7.	Count	0	0	1	1	0	2
	Row Pct	0.0	0.0	50.0	50.0	0.0	4.8
	Col Pct	0.0	0.0	5.9	5.9	0.0	
	Tot Pct	0.0	0.0	2.4	2.4	0.0	
9.	Count	0	1	0	1	0	2
	Row Pct	0.0	50.0	0.0	50.0	0.0	4.8
	Col Pct	0.0	33.3	0.0	5.9	0.0	
	Tot Pct	0.0	2.4	0.0	2.4	0.0	
10.	Count	0	0	1	0	1	2
	Row Pct	0.0	0.0	50.0	0.0	50.0	4.8
	Col Pct	0.0	0.0	5.9	0.0	33.3	
	Tot Pct	0.0	0.0	2.4	0.0	2.4	
11.	Count	1	0	9	5	1	16
	Row Pct	6.3	0.0	56.3	31.3	6.3	38.1
	Col Pct	50.0	0.0	52.9	29.4	33.3	
	Tot Pct	2.4	0.0	21.4	11.9	2.4	
12.	Count	0	1	1	4	0	6
	Row Pct	0.0	16.7	16.7	66.7	0.0	14.3
	Col Pct	0.0	33.3	5.9	23.5	0.0	
	Tot Pct	0.0	2.4	2.4	9.5	0.0	
Column Total	Count	2	3	17	17	3	42
	Pct	4.8	7.1	40.5	40.5	7.1	100.0

Dusk-Dawn Only (42 cases)

11 + 12 + 1 o'clock: 78.6%

TABLE 6.11.8. MOTORCYCLE RIDER PRE-CRASH LINE-OF-SIGHT TO THE OTHER VEHICLE (OSIDs)



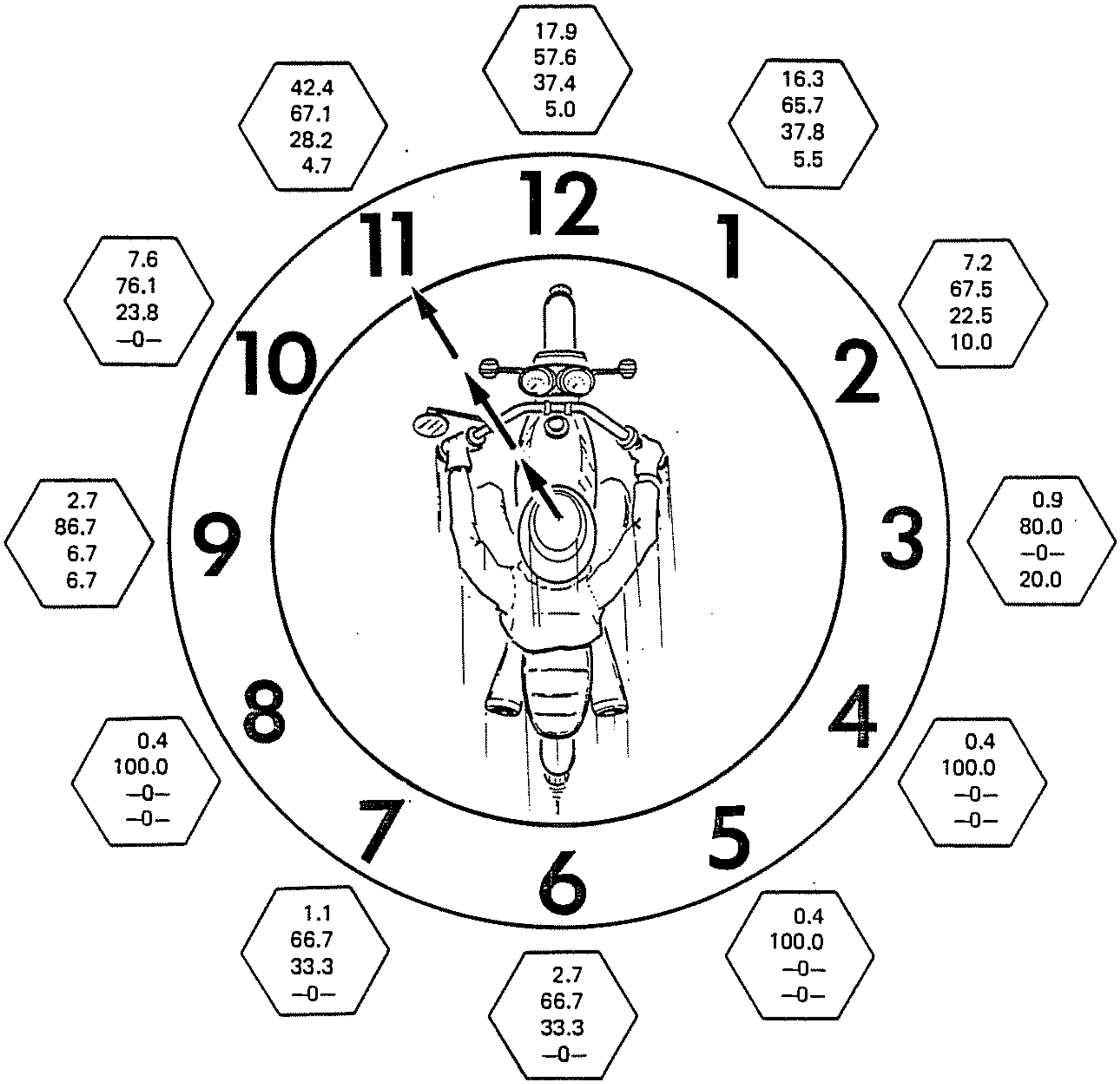
DUSK-DAWN ONLY (42)
11 + 12 + 1: 78.6%

TABLE 6.11.9. BEARING OF OTHER VEHICLE AS SEEN FROM MOTORCYCLE VERSUS MOTORCYCLE HEADLAMP OPERATION

Bearing of the Other Vehicle	Count Row Pct Col Pct Tot Pct	Motorcycle Headlamp Operation						Row Total
		Not Equipped	Equip., Not Oper	Oper, Not On	On at Accident	Equip., Not Known	Unknown If On	
1.	Count	1	0	50	34	2	2	90
	Row Pct	1.1	0.0	55.6	37.8	2.2	3.3	16.3
	Col Pct	7.7	0.0	15.0	20.5	14.3	23.1	
	Tot Pct	0.2	0.0	9.1	6.2	0.4	0.5	
2.	Count	3	1	23	9	2	2	40
	Row Pct	7.5	2.5	57.5	22.5	5.0	5.0	7.2
	Col Pct	23.1	7.7	6.9	5.4	14.3	15.4	
	Tot Pct	0.5	0.2	4.2	1.6	0.4	0.4	
3.	Count	0	0	4	0	1	0	5
	Row Pct	0.0	0.0	80.0	0.0	20.0	0.0	0.9
	Col Pct	0.0	0.0	1.2	0.0	7.1	0.0	
	Tot Pct	0.0	0.0	0.7	0.0	0.2	0.0	
4.	Count	0	0	2	0	0	0	2
	Row Pct	0.0	0.0	100.0	0.0	0.0	0.0	0.4
	Col Pct	0.0	0.0	0.6	0.0	0.0	0.0	
	Tot Pct	0.0	0.0	0.4	0.0	0.0	0.0	
5.	Count	0	0	2	0	0	0	2
	Row Pct	0.0	0.0	100.0	0.0	0.0	0.0	0.4
	Col Pct	0.0	0.0	0.6	0.0	0.0	0.0	
	Tot Pct	0.0	0.0	0.4	0.0	0.0	0.0	
6.	Count	1	0	9	5	0	0	15
	Row Pct	6.7	0.0	60.0	33.3	0.0	0.0	2.7
	Col Pct	7.7	0.0	2.7	3.0	0.0	0.0	
	Tot Pct	0.2	0.0	1.6	0.9	0.0	0.0	
7.	Count	0	0	4	2	0	0	6
	Row Pct	0.0	0.0	66.7	33.3	0.0	0.0	1.1
	Col Pct	0.0	0.0	1.2	1.2	0.0	0.0	
	Tot Pct	0.0	0.0	0.7	0.4	0.0	0.0	
8.	Count	0	0	0	2	0	0	2
	Row Pct	0.0	0.0	0.0	100.0	0.0	0.0	0.4
	Col Pct	0.0	0.0	0.0	1.2	0.0	0.0	
	Tot Pct	0.0	0.0	0.0	0.4	0.0	0.0	
9.	Count	0	0	13	1	1	0	15
	Row Pct	0.0	0.0	86.7	6.7	6.7	0.0	2.7
	Col Pct	0.0	0.0	3.9	0.6	7.1	0.0	
	Tot Pct	0.0	0.0	2.4	0.2	0.2	0.0	
10.	Count	3	5	24	10	0	0	42
	Row Pct	7.1	11.9	57.1	23.8	0.0	0.0	7.6
	Col Pct	23.1	38.5	7.2	6.0	0.0	0.0	
	Tot Pct	0.5	0.9	4.3	1.8	0.0	0.0	
11.	Count	5	7	145	66	6	5	234
	Row Pct	2.1	3.0	62.0	28.2	2.6	2.1	42.4
	Col Pct	38.5	53.8	43.5	39.8	42.9	38.5	
	Tot Pct	0.9	1.3	26.3	12.0	1.1	0.9	
12.	Count	0	0	57	37	2	3	99
	Row Pct	0.0	0.0	57.6	37.4	2.0	3.0	17.9
	Col Pct	0.0	0.0	17.1	22.3	14.3	23.1	
	Tot Pct	0.0	0.0	10.3	6.7	0.4	0.5	
Column Total		13 2.4	13 2.4	333 60.3	166 30.1	14 2.5	13 2.4	552 100.0

Daylight Only (552 Cases)
11 + 12 + 1 o'clock: 76.6%

TABLE 6.11.10. MOTORCYCLE RIDER PRE-CRASH LINE-OF-SIGHT TO OTHER VEHICLE (OSIDs)



DAYLIGHT ONLY (552)
11 + 12 + 1: 76.6%

factor related by these figures is the effectiveness of the headlamp being on in daytime as an accident countermeasure. It is clear that the headlamp is most likely to be effective along those lines-of-sight where the headlamp would offer high contrast conspicuity, i.e., only 11, 12, and 1 o'clock orientations. The daytime data show:

Clock line-of-sight	11	12	1
Accident Frequency	42.4	17.9	16.3
Headlamp not equipped, or off, or inoperative	67.1	57.6	56.7
Headlamp on	28.2	37.4	37.8
Unknown/Undetermined	4.7	5.0	5.5

Exposure data show that at least 60% of the population-at-risk had headlamps on in the daytime. Consequently, those motorcycles with headlamps on in daylight would be under-represented in the accident population and the countermeasure is effective. Also, it is possible that the voluntary use of the headlamp on in the daylight is an indication of the more knowledgeable or cautious motorcycle rider, who would be less accident-involved. However, the overall effect shown in these data is a great potential of reduced accident involvement by headlamp use in daylight.

While data were not recorded for all 900 accident cases, a sample of vehicle examinations showed that those motorcycles with the headlamp on had the following:

Low beam selected	87%
High beam selected	6%
Unknown or undetermined	7%

So, the data related for headlamp effectiveness may be assumed in the majority to represent the contribution of low beam operation.

6.12 Crash Bar Effectiveness

The effectiveness of crash bars was investigated by comparing motorcycle equipment and the incidence of injuries to the rider's ankle-foot, lower leg, knee and thigh regions. Table 6.12.1 shows the motorcycle crash bar equipment for the 900 on-scene, in-depth accident investigation cases. This table shows that 163 accident-involved motorcycles were equipped with some kind of crash bars, i.e., 18.1%. Engine "case-savers" were not counted as crash bars since those accessories serve only to protect the mechanical components and offer no substantial obstacle to an injury source. Note also that 230 (25.6%) of those motorcycles were not involved in collision with another vehicle, although another vehicle may have been involved in accident causation in approximately fifty of those cases; collisions with other vehicles were involved in 667 (74.1%).

There was no attempt to evaluate the crash bar configuration on an individual accident case; some crash bars were flimsy tube structures attached with U-bolts or hose clamps while others were substantial integral structures. Individual cases

TABLE 6.12.1. CRASHBAR-EQUIPPED VERSUS MULTIPLE/SINGLE VEHICLE ACCIDENT (OSIDs)

Crashbar	Count Row Pct Col Pct Tot Pct	Single Vehicle	Multi-Vehicle	Unknown	Row Total
None		193 26.2 83.9 21.4	540 73.4 81.0 60.0	3 0.4 100.0 0.3	736 81.8
Yes		36 22.1 15.7 4.0	127 77.9 19.0 14.1	0 0.0 0.0 0.0	163 18.1
Unknown		1 100.0 0.4 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.1
	Column Total	230 25.6	667 74.1	3 0.3	900 100.0

showed examples of success as well as failure of the minimum strength crash bars and then failure as well as success of the more substantial crash bars.

Table 6.12.2 shows the investigator's evaluation of the crash bar damage. In 18 of the crash bar equipped motorcycles, the crash bars were agents of injury, accounting for 22 discrete injuries as the contact surface.

TABLE 6.12.2. DAMAGE TO CRASH BARS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
No Damage	0.	9	1.0	5.5
Damage, No Injury	1.	136	15.1	83.4
Damage + Injury	2.	18	2.0	10.9
Damage, Injury Unknown	7.	2	0.2	1.2
Unknown	8.	1	0.1	Missing
N.A., No Crashbars	9.	734	81.6	Missing
	TOTAL	900	100.0	100.0

Crash bars have the prospect of protecting the lower limbs in the event of collision with another vehicle, or during a fall to the roadway. The regions of the body most likely to be involved are the somatic regions of the thigh (T), knee (K), lower leg (L), and ankle-foot (Q). In the 900 accident cases, there were 1321 discrete injuries to these "protectable" regions. Table 6.12.3 shows the distribution of these individual injuries to the protectable regions, for the 900 motorcycles with and without crash bars. The motorcycles equipped with crash bars (18.1%) accounted for an equivalent share (17.9%) of the injuries to those regions of the body that are assumed to be protectable by crash bars. Consequently, no advantage is obvious from the use of crash bars.

TABLE 6.12.3. INJURY SEVERITY TO PROTECTABLE REGIONS (T + K + L + Q) BY MOTORCYCLE CRASHBAR USAGE (OSIDs)

Crashbar	Count Row Pct Col Pct Tot Pct	Injury Severity Minor	Moderate	Severe	Serious	Critical	Unknown	Total
None		822 75.8 82.2 62.2	163 15.0 83.6 12.3	64 5.9 75.3 4.8	34 3.1 87.2 2.6	1 0.1 100.0 0.1	1 0.1 100.0 0.1	1085 82.1
Yes		178 75.4 17.8 13.5	32 13.6 16.4 2.4	21 8.9 24.7 1.6	5 2.1 12.8 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	236 17.9
	Column	1000 75.7	195 14.8	85 6.4	39 3.0	1 0.1	1 0.1	1321 100.0

Some explanation of the severe, serious and critical injuries will give perspective to these extreme injuries. The one case of AIS:5 was traumatic high amputation of the thigh due to leg entrapment in the collision surface. The great part of the AIS:4 and AIS:3 injuries are in that region of the lower leg, and because of the nature of those injuries, the two severity levels should be considered together rather than separate and distinctly different injury levels. For example, a compound, comminuted fracture of the tibia (AIS:3) differs only slightly in total effect from a compound, comminuted fracture of the tibia and fibula with severe tissue destruction (given AIS:4 in these data).

Additional details of crash bar performance are shown in Table 6.12.4, where the severity of injuries to the protectable regions are shown for the single and multiple vehicle collisions. Recall from Table 6.12.1 that the motorcycles were crash bar equipped in 15.7% of the single vehicle collisions and 19.0% of the multiple vehicle collisions. This comparison shows no favor or advantage to the use of crash bars in either single or multiple vehicle collisions. A popular concept of past time was that crash bars would support the motorcycle if it falls to the roadway thereby preventing injury to the rider's leg which could be trapped between the motorcycle and the roadway. The data offers no support for this concept.

TABLE 6.12.4. CRASHBAR EFFECTIVENESS IN SINGLE AND MULTIPLE VEHICLE COLLISIONS LEG INJURY SEVERITY BY CRASHBAR USAGE

Crashbar	Count / Row Pct / Col Pct / Tot Pct	Injury Severity: Minor	Moderate	Severe	Serious	Critical	Unknown	Total
Single Vehicle Collisions								
None		161 79.7 83.9 67.4	35 17.3 85.4 14.6	5 2.5 100.0 2.1	1 0.5 100.0 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	202 84.5
Yes		31 83.8 16.1 13.0	6 16.2 14.6 2.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	37 15.5
	Column Total	192 80.3	41 17.2	5 2.1	1 0.4	0 0.0	0 0.0	239 100.0
Multiple Vehicle Collisions								
None		658 74.9 81.7 61.0	127 14.4 83.0 11.8	59 6.7 73.8 5.5	33 3.8 86.8 3.1	1 0.1 100.0 0.1	1 0.1 100.0 0.1	879 81.5
Yes		147 73.9 18.3 13.6	26 13.1 17.0 2.4	21 10.6 26.3 1.9	5 2.5 13.2 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	199 18.5
	Column Total	805 74.7	153 14.2	80 7.4	38 3.5	1 0.1	1 0.1	1078 100.0

Another popular concept of past time was that crash bars could prevent the intrusion of an automobile bumper or front corner and prevent injury to the rider's leg which could be trapped between the motorcycle and the automobile. In some cases where there is no initial collision contact other than the leg entrapment, injuries would be limited only if some very substantial structure were between the rider leg and the automobile. In present time, the <u>only</u> structure of <u>sufficient</u> substance is the heavy cylinder of a horizontally opposed engine, e.g., BMW.

Contemporary crash bars do not have the strength, coverage, or (in many instances) the opportunity to have any significant effect in reducing injuries to the protectable regions. If the collision contact for the motorcycle is at the front, or front sides, of the motorcycle (61.9%), the impact response of the rider is to slide forward above the tank. Also, the pitching response at impact lifts the rear of the motorcycle thus partly vaulting the rider and elevating the protectable regions of the body. Of course, less vaulting of the motorcycle occupant(s) occurs due to motorcycle pitching when a passenger is present.

An examination of the injuries to the individual regions provides an added perspective of crash bar effectiveness. Tables 6.12.5, 6, 7 and 8 show that crash bar equipped motorcycles (18.1%) accounted for 19.4% of the thigh injuries, 20.1% of the knee injuries, 19.9% of the lower leg injuries, but only 9.4% of the ankle-foot injuries. The advantage of reduced ankle-foot injuries is lost by the disadvantage of increased knee, lower leg, and thigh injuries. In other words, crash bar performance in this study shows that crash bars help some, but also hurt some and the overall effect is no advantage.

TABLE 6.12.5. INJURY SEVERITY TO THIGH-UPPER LEG ONLY
BY CRASHBAR USAGE

Crashbar	Count Row Pct Col Pct Tot Pct	Injury Severity					Total
		Minor	Moderate	Severe	Serious	Critical	
None		129 75.9 81.1 61.1	26 15.3 81.3 12.3	12 7.1 70.6 5.7	2 1.2 100.0 0.9	1 0.6 100.0 0.5	170 80.6
Yes		30 73.2 18.9 14.2	6 14.6 18.8 2.8	5 12.2 29.4 2.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	41 19.4
	Column Total	159 75.4	32 15.2	17 8.1	2 0.9	1 0.5	211 100.0

TABLE 6.12.6. INJURY SEVERITY TO KNEE ONLY
BY CRASHBAR USAGE

Crashbar	Count Row Pct Col Pct Tot Pct	Injury Severity				Total
		Minor	Moderate	Severe	Serious	
None		302 87.5 80.5 69.9	32 9.3 76.2 7.4	9 2.6 69.2 2.1	2 0.6 100.0 0.5	345 79.9
Yes		73 83.9 19.5 16.9	10 11.5 23.8 2.3	4 4.6 30.8 0.9	0 0.0 0.0 0.0	87 20.1
	Column Total	375 86.8	42 9.7	13 3.0	2 0.5	432 100.0

TABLE 6.12.7. INJURY SEVERITY TO LOWER LEG ONLY BY CRASHBAR USAGE

Crashbar	Count Row Pct Col Pct Tot Pct	Injury Severity					Total
		Minor	Moderate	Severe	Serious	Unknown	
None		237 70.1 80.3 56.2	42 12.4 79.2 10.0	29 8.6 74.4 6.9	29 8.6 85.3 6.9	1 0.3 100.0 0.2	338 80.1
Yes		58 69.0 19.7 13.7	11 13.1 20.8 2.6	10 11.9 25.6 2.4	5 6.0 14.7 1.2	0 0.0 0.0 0.0	84 19.9
	Column Total	295 69.9	53 12.6	39 9.2	34 8.1	1 0.2	422 100.0

TABLE 6.12.8. INJURY SEVERITY TO ANKLE-FOOT ONLY BY CRASHBAR USAGE

Crashbar	Count Row Pct Col Pct Tot Pct	Injury Severity				Total
		Minor	Moderate	Severe	Serious	
None		154 66.4 90.1 60.2	63 27.2 92.6 24.6	14 6.0 87.5 5.5	1 0.4 100.0 0.4	232 90.6
Yes		17 70.8 9.9 6.6	5 20.8 7.4 2.0	2 8.3 12.5 0.8	0 0.0 0.0 0.0	24 9.4
	Column Total	171 66.8	68 26.6	16 6.3	1 0.4	256 100.0

The only truly substantial structure which could interrupt the intrusion of an automobile bumper or front corner is an engine cylinder (or two). Table 6.12.9 shows the injuries to the thigh, knee, lower leg, and ankle-foot for all BMW motorcycles encountered in this study. All BMW's in the study were the two-cylinder horizontally opposed cylinder configuration, and the BMW's were 1.6% of the accident case motorcycles but accounted for 0.83% of the injuries in the "protectable" regions.

Count Row Pct Col Pct Tot Pct	Injury Severity Minor 1	Row Total
Crashbar		
None	2 100.0 18.2 18.2	2 18.2
Yes	9 100.0 81.8 81.8	9 81.8
Column Total	11 100.0	11 100.0

TABLE 6.12.9. CRASHBAR USAGE VERSUS INJURY TO THIGH, KNEE, LOWER LEG, ANKLE-FOOT FOR BMW

Table 6.12.10 shows the injuries to the thigh, knee, lower leg and ankle-foot for the Honda GL-1000 which was the 4-cylinder horizontally opposed cylinder configuration. The GL-1000 accounts for 1.1% of the accident population and accounted for 1.1% of the injuries in the "protectable" regions.

TABLE 6.12.10. CRASHBAR USAGE VERSUS INJURY TO THIGH, KNEE, LOWER LEG, ANKLE-FOOT FOR HONDA GL-1000

Count Row Pct Col Pct Tot Pct	Injury Severity			Row Total
	Minor 1	Moderate 2	Severe 3	
Crashbar				
None	6 75.0 66.7 42.9	1 12.5 33.3 7.1	1 12.5 50.0 7.1	8 57.1
Yes	3 50.0 33.3 21.4	2 33.3 66.7 14.3	1 16.7 50.0 7.1	6 42.9
Column Total	9 64.3	3 21.4	2 14.3	14 100.0

Table 6.12.11 shows the injuries to the same regions for all Moto Guzzi motorcycles encountered in the accident study. All Moto Guzzis in the study were the V-twin engine configuration with shaft drive. The Moto Guzzis were 0.8% of the accident population and accounted for 0.68% of the injuries to the "protectable" regions.

TABLE 6.12.11. CRASHBAR USAGE VERSUS INJURY TO THIGH, KNEE, LOWER LEG, ANKLE-FOOT FOR MOTO GUZZI

Count Row Pct Col Pct Tot Pct	Injury Severity			
	Minor 1	Moderate 2	Severe 3	Row Total
Crashbar				
None	0 0.0 0.0 0.0	1 50.0 100.0 11.1	1 50.0 50.0 11.1	2 22.2
Yes	6 85.7 100.0 66.7	0 0.0 0.0 0.0	1 14.3 50.0 11.1	7 77.8
Column Total	6 66.7	1 11.1	2 22.2	9 100.0

For that whole group of motorcycles having large, heavy cylinders in positions which could conceivably protect the rider's legs (BMW + GL-1000 +MG), those motorcycles comprised 3.5% of the accident population and accounted for 2.61% of the injuries to the protectable regions.

Tables 6.12.12 and 13 show the distribution and severity of somatic injuries in the single vehicle collisions. Tables 6.12.14 and 15 show the distribution and severity of somatic injuries in the multiple vehicle collisions. Crashbar equipped motorcycles have less than their share of ankle-foot injuries, especially in the multiple vehicle accidents. It appears that the crashbar equipment on these accident-involved motorcycles has a favorable effect only in limiting injuries to the region of the ankle-foot.

6.13 Vehicle Defects

In general, vehicle defects are rare and the contribution to accident causation is small. Vehicle Failure of the motorcycle was the accident precipitating factor in 2.8% of the on-scene, in-depth accident investigation cases. The great part of the cases involved tire puncture flats and obvious maintenance defects.

TABLE 6.12.12. SINGLE VEHICLE SOMATIC INJURY DISTRIBUTION (OSIDs)

Crashbar	Count Row Pct Col Pct Tot Pct	Upper Arm A	Back B	Chest C	Elbow E	Knee K	Lower Leg L	Abdomen M	Whole Body O	Pelvic Hip P	Row Total
None		20 3.4 80.0 2.9	18 3.1 81.8 2.6	61 10.4 96.8 8.9	30 5.1 75.0 4.4	85 14.4 83.3 12.4	48 8.1 85.7 7.0	33 5.6 94.3 4.8	2 0.3 100.0 0.3	34 5.8 77.3 5.0	589 86.0
Yes		5 5.2 20.0 0.7	4 4.2 18.2 0.6	2 2.1 3.2 0.3	10 10.4 25.0 1.5	17 17.7 16.7 2.5	8 8.3 14.3 1.2	2 2.1 5.7 0.3	0 0.0 0.0 0.0	10 10.4 22.7 1.5	96 14.0
	Column Total	25 3.6	22 3.2	63 9.2	40 5.8	102 14.9	56 8.2	35 5.1	2 0.3	44 6.4	685 100.0

Crashbar	Count Row Pct Col Pct Tot Pct	Ankle Foot Q	Forearm R	Shoulders S	Thigh T	Unknown U	Wrist/ Hand W	Upper Extremities X	Trunk Y	Row Total
None		41 7.0 87.2 6.0	51 8.7 86.4 7.4	41 7.0 83.7 6.0	28 4.8 82.4 4.1	1 0.2 100.0 0.1	95 16.1 92.2 13.9	0 0.0 0.0 0.0	1 0.2 50.0 0.1	589 86.0
Yes		6 6.3 12.8 0.9	8 8.3 13.6 1.2	8 8.3 16.3 1.2	6 6.3 17.6 0.9	0 0.0 0.0 0.0	8 8.3 7.8 1.2	1 1.0 100.0 0.1	1 1.0 50.0 0.1	96 14.0
	Column Total	47 6.9	59 8.6	49 7.2	34 5.0	1 0.1	103 15.0	1 0.1	2 0.3	685 100.0

TABLE 6.12.13. SINGLE VEHICLE SOMATIC INJURY SEVERITY (OSIDs)

Crashbar	Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
None		437 74.2 84.2 63.8	90 15.3 88.2 13.1	33 5.6 97.1 4.8	17 2.9 94.4 2.5	10 1.7 100.0 1.5	2 0.3 100.0 0.3	589 86.0
Yes		82 85.4 15.8 12.0	12 12.5 11.8 1.8	1 1.0 2.9 0.1	1 1.0 5.6 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	96 14.0
	Column Total	519 75.8	102 14.9	34 5.0	18 2.6	10 1.5	2 0.3	685 100.0

TABLE 6.12.14. MULTIPLE VEHICLE SOMATIC INJURY DISTRIBUTION (OSIDs)

Crashbar	Count Row Pct Col Pct Tot Pct	Upper Arm A	Back B	Chest C	Elbow E	Knee K	Lower Leg L	Abdomen M	Whole Body O	Pelvic Hip P	Row Total
None		61	85	109	109	259	288	144	3	100	1881
		3.2	4.5	5.8	5.8	13.8	15.3	7.7	0.2	5.3	81.1
		83.6	77.3	75.7	85.8	78.7	79.1	80.4	100.0	76.9	
		2.6	3.7	4.7	4.7	11.2	12.4	6.2	0.1	4.3	
Yes		12	25	35	18	70	76	35	0	30	438
		2.7	5.7	8.0	4.1	16.0	17.4	8.0	0.0	6.8	18.9
		16.4	22.7	24.3	14.2	21.3	20.9	19.6	0.0	23.1	
		0.5	1.1	1.5	0.8	3.0	3.3	1.5	0.0	1.3	
	Column Total	73	110	144	127	329	364	179	3	130	2319
		3.1	4.7	6.2	5.5	14.2	15.7	7.7	0.1	5.6	100.0

Crashbar	Count Row Pct Col Pct Tot Pct	Ankle Foot Q	Forearm R	Shoulders S	Thigh T	Unknown U	Wrist/ Hand W	Upper Extremities X	Trunk Y	Row Total
None		191	96	88	141	2	199	4	2	1881
		10.2	5.1	4.7	7.5	0.1	10.6	0.2	0.1	81.1
		91.4	84.2	78.6	80.1	66.7	83.6	80.0	66.7	
		8.2	4.1	3.8	6.1	0.1	8.6	0.2	0.1	
Yes		18	18	24	35	1	39	1	1	438
		4.1	4.1	5.5	8.0	0.2	8.9	0.2	0.2	18.9
		8.6	15.8	21.4	19.9	33.3	16.4	20.0	33.3	
		0.8	0.8	1.0	1.5	0.0	1.7	0.0	0.0	
	Column Total	209	114	112	176	3	238	5	3	2319
		9.0	4.9	4.8	7.6	0.1	10.3	0.2	0.1	100.0

TABLE 6.12.15. MULTIPLE VEHICLE SOMATIC INJURY SEVERITY (OSIDs)

Crashbar	Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
None		1418	229	135	67	23	8	1	1881
		75.4	12.2	7.2	3.6	1.2	0.4	0.1	81.1
		81.6	81.8	75.0	82.7	76.7	80.0	100.0	
		61.1	9.9	5.8	2.9	1.0	0.3	0.0	
Yes		319	51	45	14	7	2	0	438
		72.8	11.6	10.3	3.2	1.6	0.5	0.0	18.9
		18.4	18.2	25.0	17.3	23.3	20.0	0.0	
		13.8	2.2	1.9	0.6	0.3	0.1	0.0	
	Column Total	1737	280	180	81	30	10	1	2319
		74.9	12.1	7.8	3.5	1.3	0.4	0.0	100.0

The evaluation of the mechanical condition of the motorcycle showed no significant relation to accident causation. For example, tire condition was evaluated as "poor" or "fair" for less than 10% of the tires examined on the accident-involved motorcycles. All but two cases were unrelated to accident causation; one case involved an ineffective repair of a previous puncture flat and the other case involved a defective butt splice in a tube which caused an (undetected) slow leak and eventual flat.

The systems of the motorcycle were without failure and without contribution to accident causation. There were no cases of exploding batteries, electrical failures at night, engine or transmission failures, waterlogged brake surface, or "stuck" throttles. In two cases the riders stated that a "stuck" throttle caused then to lose control and run wide on a turn. A thorough investigation of the accident circumstances and detailed examination of the motorcycle proved these contentions to be false and simply inaccurate reconstructions by the rider.

Vehicle dynamics problems of "speed wobbles" or "weaves" were clearly attributable to an obvious maintenance defect or more fundamental rider control problems, i.e., rider lost wheelie or ran wide on a turn and ran off the road.

Mirrors were never criticized directly by the rider as accident related in performance or function. Evaluation of the accident events showed that detection of hazards by mirrors was not a factor in those very few accidents where the hazard was in that rearward direction.

Turn signals did not contribute adversely in any way.

Kill switches or kill buttons had no favorable or unfavorable contribution in the accident events.

The motorcycle horn has little function or favor in the precrash events. Table 6.13.1 shows that the motorcycle horn is rarely used in an attempt to ward off the hazard (6.7%). When the horn is needed, it is usually a feeble aural message that fails in warning. For example, the motorcycle in a traffic lane stops behind a van stopped at a traffic signal. The van has intruded into an occupied crosswalk and backs up to the distress of the motorcycle rider. Frantic use of the weak horn and rapid paddling backwards do not prevent a low energy collision contact.

TABLE 6.13.1. MOTORCYCLE HORN USE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Did MC Use Horn to Warn OV?				
Yes	1.	47	5.2	6.7
No	2.	656	72.9	93.3
Unknown	8.	38	4.2	Missing
Not Applicable	9.	159	17.7	Missing
	TOTAL	900	100.0	100.0

A review of the 3600 police traffic accident cases showed a contrast in the evaluation of vehicle defects. Table 6.13.2 shows that 8.2% of the motorcycles were judged defective. Of course, those cases with obvious puncture flats were appropriately included but an extraordinary number of cases included motorcycles with tires judged to have inadequate tread depth. A cross check between the 900 on-scene, in-depth cases showed this judgement to be unqualified and also unrelated to the accident events and accident causation. There was no credibility established for the evaluation of defects by the traffic accident reports.

TABLE 6.13.2. MOTORCYCLE CONDITION (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
OK	1.	2939	81.6	91.8
Defective	2.	264	7.3	8.2
Unknown	8.	397	11.0	Missing
	TOTAL	3600	100.0	100.0

6.14 Other Vehicle Involved in the Accident with the Motorcycle

Table 6.14.1 shows the object in collision contact with the motorcycle for the on-scene, in-depth accident cases. Those data are shown for the 900 cases then for the 54 fatal cases within the basic data. The involvement with other motorcycles was exclusively in parallel paths with low energy contact but subsequent loss of control by the motorcycle rider.

Table 6.14.2 (Appendix C.2) shows the manufacturer of the automobile involved in collision contact with the motorcycle.

Table 6.14.3 (Appendix C.2) shows the model type for the 900 on-scene, in-depth accident cases.

Table 6.14.4 (Appendix C.2) presents the vehicle size information for both the 900 on-scene, in-depth accident cases and the 3600 traffic accident reports.

Table 6.14.5 (Appendix C.2) shows the collision contact points (not necessarily injury surfaces) on the other vehicle involved in collision with the motorcycle. Certain areas of collision contact are summarized as follows:

Front and Front Corner

XF01	121	
XF03	61	
XS01	21	
XS03	44	
TOTAL	247	(36.9% of multiple vehicle accidents)

Side Fender, Door & Pillars

XS02	65	
XS06	59	
XS12	10	
XS14	49	
TOTAL	183	(27.3% of multiple vehicle accidents)

Tires, Wheels & Undercarriage

XS21	29	
XB27	2	
XS27	4	
TOTAL	35	(5.2% of multiple vehicle accidents)

Other Motorcycles, Own Handlebars, Forks, Front Wheel

MC05	4	
MC08	1	
MC11	4	
TOTAL	9	(37.5% of the 24 contacts with M/C components)

TABLE 6.14.1. OBJECT STRUCK BY MOTORCYCLE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
OSIDs				
Passenger Car	1.	588	65.3	65.3
Other Motorcycle	2.	27	3.0	3.0
Fixed Object	3.	40	4.4	4.4
Animal	4.	8	0.9	0.9
Roadway	5.	172	19.1	19.1
Other 4-Wheel Vehicle	6.	48	5.3	5.3
Other	7.	17	1.9	1.9
	TOTAL	900	100.0	100.0
Fatal OSIDs Only				
Passenger Car	1.	27	50.0	50.0
Other Motorcycle	2.	4	7.4	7.4
Fixed Object	3.	11	20.4	20.4
Roadway	5.	7	13.0	13.0
Other 4-Wheel Vehicle	6.	5	9.3	9.3
	TOTAL	54	100.0	100.0

7.0 MOTORCYCLE RIDER, PASSENGER, AND OTHER VEHICLE DRIVER CHARACTERISTICS

This section deals with the human factors involved in the motorcycle accidents. The general data describe the characteristics of the motorcycle rider, i.e., age, experience, license, training, education, height, weight, etc. In addition, there are included more specific data synthesized or collected which relates to the collision avoidance performance of the motorcycle rider, e.g., front brake use, collision avoidance decisions, time for collision avoidance, alcohol and drug involvement, etc. Of course, it is expected that any rider involved in an accident did not demonstrate success in collision avoidance performance, and the data collected here attempt to define and describe the errors made by the motorcycle rider in those precrash events.

7.1 Motorcycle Rider Age

Rider age distributions were determined for three groups of data.

Table 7.1.1 shows the distribution of motorcycle rider age for the 900 on-scene, in-depth accident investigation cases. The median age is 24.8 years, and the age group of 17 through 26 is 54.8% of the accident-involved riders.

Table 7.1.2 shows the distribution of motorcycle rider age for the 54 fatalities of the 900 on-scene, in-depth accident cases. The median age is 26 and the age group of 17 through 26 is 50.% of the fatally injured motorcycle riders.

Table 7.1.3 shows the motorcycle rider age from the 3600 traffic accident reports analyzed. The median age is 22.9 years and the age group of 17 through 26 is 62.6% of the accident-involved riders.

7.2 Motorcycle Rider Sex, Marital Status, Children

Table 7.2.1 (Appendix C.3) shows that the male motorcycle riders are 96.2% of the total; female riders are 3.8% of the 900 on-scene, in-depth cases. Analysis of the 3600 traffic accident reports shows female riders were 2.9% of that accident population.

The one case of the on-scene, in-depth investigations where rider sex was unknown was a Hollywood moped rider.

Table 7.2.2 (Appendix C.3) shows the marital status of the motorcycle rider for the 900 on-scene, in-depth accident cases.

Table 7.2.3 (Appendix C.3) shows the number of children for the accident-involved motorcycle rider.

TABLE 7.1.1. MOTORCYCLE RIDER AGE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Age, Years	9.	1	0.1	0.1	0.1
	12.	2	0.2	0.2	0.3
	13.	1	0.1	0.1	0.4
	14.	2	0.2	0.2	0.7
	15.	3	0.3	0.3	1.0
	16.	5	0.6	0.6	1.6
	17.	21	2.3	2.3	3.9
	18.	36	4.0	4.0	7.9
	19.	36	4.0	4.0	11.9
	20.	62	6.9	6.9	18.8
	21.	64	7.1	7.1	25.9
	22.	63	7.0	7.0	32.9
	23.	58	6.4	6.4	39.3
	24.	52	5.8	5.8	45.1
	25.	56	6.2	6.2	51.3
	26.	46	5.1	5.1	56.4
	27.	42	4.7	4.7	61.1
	28.	35	3.9	3.9	65.0
	29.	31	3.4	3.4	68.4
	30.	36	4.0	4.0	72.4
	31.	21	2.3	2.3	74.8
	32.	19	2.1	2.1	76.9
	33.	26	2.9	2.9	79.8
	34.	19	2.1	2.1	81.9
	35.	12	1.3	1.3	83.2
	36.	19	2.1	2.1	85.3
	37.	19	2.1	2.1	87.4
	38.	10	1.1	1.1	88.6
	39.	7	0.8	0.8	89.3
	40.	10	1.1	1.1	90.4
	41.	1	0.1	0.1	90.6
	42.	7	0.8	0.8	91.3
	43.	5	0.6	0.6	91.9
	44.	6	0.7	0.7	92.6
	45.	2	0.2	0.2	92.8
	46.	6	0.7	0.7	93.4
	47.	5	0.6	0.6	94.0
	48.	3	0.3	0.3	94.3
	49.	6	0.7	0.7	95.0
	50.	1	0.1	0.1	95.1
	51.	3	0.3	0.3	95.4
	52.	1	0.1	0.1	95.6
	53.	5	0.6	0.6	96.1
	54.	3	0.3	0.3	96.4
	55.	5	0.6	0.6	97.0
	56.	4	0.4	0.4	97.4
	57.	1	0.1	0.1	97.6
	58.	1	0.1	0.1	97.7
	59.	2	0.2	0.2	97.9
	61.	2	0.2	0.2	98.1
	62.	1	0.1	0.1	98.2
	64.	3	0.3	0.3	98.6
	66.	2	0.2	0.2	98.8
	70.	1	0.1	0.1	98.9
	75.	1	0.1	0.1	99.0
Unknown	98.	9	1.0	1.0	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.1.2. MOTORCYCLE RIDER AGE, FATAL CASES (OSID FATALS ONLY)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Age, Years	18.	2	3.7	3.7	3.7
	19.	1	1.9	1.9	5.6
	20.	4	7.4	7.4	13.0
	21.	4	7.4	7.4	20.4
	22.	1	1.9	1.9	22.2
	23.	4	7.4	7.4	29.6
	24.	3	5.6	5.6	35.2
	25.	5	9.3	9.3	44.4
	26.	3	5.6	5.6	50.0
	28.	1	1.9	1.9	51.9
	29.	1	1.9	1.9	53.7
	30.	3	5.6	5.6	59.3
	31.	1	1.9	1.9	61.1
	32.	2	3.7	3.7	64.8
	33.	3	5.6	5.6	70.4
	34.	2	3.7	3.7	74.1
	35.	2	3.7	3.7	77.8
	36.	1	1.9	1.9	79.6
	38.	1	1.9	1.9	81.5
	42.	2	3.7	3.7	85.2
	44.	2	3.7	3.7	88.9
	49.	1	1.9	1.9	90.7
	56.	2	3.7	3.7	94.4
	70.	1	1.9	1.9	96.3
	75.	1	1.9	1.9	98.1
Unknown	98.	1	1.9	1.9	100.0
	TOTAL	54	100.0	100.0	

TABLE 7.1.3. MOTORCYCLE RIDER AGE (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Age, Years	10.	2	0.1	0.1	0.1
	11.	1	0.0	0.0	0.1
	12.	3	0.1	0.1	0.2
	13.	6	0.2	0.2	0.3
	14.	11	0.3	0.3	0.7
	15.	22	0.6	0.6	1.3
	16.	62	1.7	1.8	3.1
	17.	149	4.1	4.3	7.3
	18.	207	5.7	5.9	13.2
	19.	279	7.7	8.0	21.2
	20.	270	7.5	7.7	28.9
	21.	256	7.1	7.3	36.2
	22.	272	7.6	7.8	44.0
	23.	231	6.4	6.6	50.6
	24.	173	4.8	4.9	55.5
	25.	191	5.3	5.5	60.9
	26.	160	4.4	4.6	65.5
	27.	115	3.2	3.3	68.8
	28.	125	3.5	3.6	72.4
	29.	121	3.4	3.5	75.8
	30.	107	3.0	3.1	78.9
	31.	88	2.4	2.5	81.4
	32.	67	1.9	1.9	83.3
	33.	68	1.9	1.9	85.2
	34.	51	1.4	1.5	86.7
	35.	59	1.6	1.7	88.4
	36.	46	1.3	1.3	89.7
	37.	35	1.0	1.0	90.7
	38.	29	0.8	0.8	91.5
	39.	27	0.7	0.8	92.3
	40.	28	0.8	0.8	93.1
	41.	20	0.6	0.6	93.7
	42.	11	0.3	0.3	94.0
	43.	23	0.6	0.7	94.6
	44.	15	0.4	0.4	95.1
	45.	14	0.4	0.4	95.5
	46.	18	0.5	0.5	96.0
	47.	11	0.3	0.3	96.3
	48.	14	0.4	0.4	96.7
	49.	16	0.4	0.5	97.1
	50.	9	0.2	0.3	97.4
	51.	4	0.1	0.1	97.5
	52.	14	0.4	0.4	97.9
	53.	11	0.3	0.3	98.2
	54.	13	0.4	0.4	98.6
	55.	9	0.2	0.3	98.9
	56.	2	0.1	0.1	98.9
	57.	7	0.2	0.2	99.1
	58.	7	0.2	0.2	99.3
	59.	5	0.1	0.1	99.5
	60.	4	0.1	0.1	99.6
	61.	3	0.1	0.1	99.7
	62.	1	0.0	0.1	99.7
	63.	3	0.1	0.1	99.8
	64.	2	0.1	0.1	99.8
	65.	2	0.1	0.1	99.9
	66.	1	0.0	0.0	99.9
	77.	1	0.0	0.0	99.9
	78.	2	0.1	0.1	100.0
Unknown	98.	97	2.7	Missing	100.0
	TOTAL	3600	100.0	100.0	

7.3 Motorcycle Rider Height and Weight

Table 7.3.1 (Appendix C.3) shows the height distribution for the accident-involved motorcycle riders. The median height is 69.2 inches.

Table 7.3.2 (Appendix C.3) shows the weight distribution for the accident-involved motorcycle riders. The median weight is 159.4 pounds.

7.4 Motorcycle Rider Occupation and Education

Table 7.4.1 shows the occupations of the 900 motorcycle riders in the on-scene, in-depth accident cases. Students are the largest component, (21.2%), and craftsmen (17.7%) and laborers (15.8%) combined to represent one-third of the total. The unemployed group (10.5%) was approximately representative of the local employment situation, and most of these unemployed were laborers or craftsmen when employed.

TABLE 7.4.1. RIDER OCCUPATION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Professional	1.	64	7.1	7.3
Mgr., Administrator	2.	24	2.7	2.7
Sales Worker	3.	13	1.4	1.5
Clerical	4.	62	6.9	7.1
Craftsman	5.	155	17.2	17.7
Operatives, Non-Trans.	6.	8	0.9	0.9
Transport Operatives	7.	27	3.0	3.1
Laborers	8.	138	15.3	15.8
Service Workers	11.	85	9.4	9.7
Housewife	13.	3	0.3	0.3
Student	14.	185	20.6	21.2
Military	15.	13	1.4	1.5
Retired	16.	5	0.6	0.6
Unemployed	17.	92	10.2	10.5
Unknown	98.	26	2.9	Missing
	TOTAL	900	100.0	100.0

Table 7.4.2 shows the equivalent information obtained from the examination of the 3600 police traffic accident reports.

Table 7.4.3 shows the educational background for the motorcycle riders in the 900 on-scene, in-depth accident cases.

The characteristics from the on-scene, in-depth data are agreeable with the traffic accident report data, except for the unknown data of the traffic accident reports.

TABLE 7.4.2. MOTORCYCLE RIDER OCCUPATION (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Professional	1.	184	5.1	7.8
Administrator	2.	116	3.2	4.9
Sales Worker	3.	62	1.7	2.6
Clerical	4.	121	3.4	5.2
Craftman	5.	312	8.7	13.3
Operatives	6.	64	1.8	2.7
Tran-Equip Operative	7.	92	2.6	3.9
Laborers	8.	433	12.0	18.5
Farmers	9.	1	0.0	0.0
Farm Laborers	10.	4	0.1	0.2
Service Worker	11.	283	7.9	12.1
Household Worker	12.	1	0.0	0.0
Housewife	13.	8	0.2	0.3
Student	14.	486	13.5	20.7
Military	15.	16	0.4	0.7
Retired	16.	5	0.1	0.2
Umemployed	17.	156	4.3	6.7
Unknown-Not Reported	98.	1256	34.9	Missing
	TOTAL	3600	100.0	100.0

TABLE 7.4.3. RIDER EDUCATION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Graduate School	1.	23	2.6	2.8
College Graduate	2.	43	4.8	5.2
Partial College	3.	297	33.0	35.9
High School Graduate	4.	230	25.6	27.8
Partial High School	5.	203	22.6	24.5
Junior High School	6.	17	1.9	2.1
Less Than 7 Years	7.	14	1.6	1.7
Unknown	8.	73	8.1	Missing
	TOTAL	900	100.0	100.0

Table 7.4.4 shows the Hollingshead Index of Social Position computed for the 900 motorcycle riders. Almost one-fifth of the cases shown are "unknown" because of the difficulty of obtaining financial information. Also, because of the sensitivity of such questioning by the interviewer, low priority was assigned to this information.

TABLE 7.4.4. RIDER INDEX OF SOCIAL POSITION (OSIDs)

Category Label		Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Class I	11-17	1.	11	1.2	1.7	1.7
Class II	11-27	2.	38	4.2	6.0	7.8
Class III	28-43	3.	103	11.4	16.3	24.1
Class IV	44-60	4.	275	30.6	43.5	67.6
Class V	61-77	5.	205	22.8	32.4	100.0
Unknown		8.	270	19.8	Missing	100.0
		TOTAL	900	100.0	100.0	

7.5 Motorcycle Rider License Qualification

Table 7.5.1 shows the license qualification for the 900 motorcycle riders in the 900 on-scene, in-depth accident cases. The standard motorcycle license endorsement or permit was held by 54.5% of these motorcyclists; 10.1% had no license or permit of any sort, 30.6% had an operator's license for other vehicles but no motorcycle license endorsement, and 1.8% were operating with a license revoked because of cumulative violation experience.

Also shown in Table 7.5.1 are the equivalent data developed from review of the 3600 police traffic accident reports.

Table 7.5.2 compares motorcycle rider license qualification with the accident precipitating factor for the 900 on-scene, in-depth accident cases. Those accidents involving motorcycle rider error show the extra participation of those riders without the motorcycle license endorsement.

Table 7.5.3 (Appendix C.3) shows the state of issue of the driver license for the 900 accident cases. Out-of-state drivers (32) were 3.4% of those cases.

7.6 Motorcycle Rider Traffic Violation and Accident Experience

Table 7.6.1 shows the recent previous traffic violation experience for the motorcycle riders involved in the 900 on-scene, in-depth accident cases. Also included is the violation experience for the 54 fatal cases within the 900 accidents.

TABLE 7.5.1. CLASS OF RIDER DRIVER LICENSE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	90	10.0	10.1
Class 1 - Commercial	1.	14	1.6	1.6
Class 2 - Chauffeur	2.	1	0.1	0.1
Class 3 - Standard	3.	256	28.4	28.9
Class 4 - Motorcycle	4.	483	53.7	54.5
Learner Permit	5.	27	3.0	3.0
Class 3 - Revoked	6.	14	1.6	1.6
Class 4 - Revoked	7.	2	0.2	0.2
Unknown	8.	13	1.4	Missing
	TOTAL	900	100.0	100.0

Driver License Motorcycle Qualified (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Yes	1.	1589	44.1	49.2
No	2.	1075	29.9	33.3
Permit Only	3.	96	2.7	3.0
Unknown-Not Reported	8.	467	13.0	14.5
N.A., No License	9.	373	10.4	Missing
	TOTAL	3600	100.0	100.0

TABLE 7.5.2. ACCIDENT PRECIPITATING FACTOR BY RIDER DRIVERS LICENSE (OSIDs)

Factor	Count Row Pct Col Pct Tot Pct	Rider License None	Class 1	Class 2	Class 3	Class 4	Learner Permit	Class 3 Revoked	Class 4 Revoked	Row Total
Phantom Vehicle		0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 50.0 0.8 0.2	2 50.0 0.4 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	4 0.5
MC Error		53 14.7 58.9 6.0	2 0.6 14.3 0.2	0 0.0 0.0 0.0	115 31.9 44.9 13.0	165 45.7 34.2 18.6	17 4.7 63.0 1.9	8 2.2 57.1 0.9	1 0.3 50.0 0.1	361 40.7
OV Violation of MC Right of Way		33 7.3 36.7 3.7	11 2.4 78.6 1.2	0 0.0 0.0 0.0	123 27.2 48.0 13.9	270 59.6 56.0 30.5	9 2.0 33.3 1.0	6 1.3 42.9 0.7	1 0.2 50.0 0.1	453 51.1
Roadway Defect		2 11.1 2.2 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 27.8 2.0 0.6	10 55.6 2.1 1.1	1 5.6 3.7 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	18 2.0
Pedestrian		0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 100.0 1.0 0.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 0.6
Animal		1 10.0 1.1 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 20.0 0.8 0.2	7 70.0 1.5 0.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	10 1.1
Vehicle Failure		0 0.0 0.0 0.0	1 4.2 7.1 0.1	0 0.0 0.0 0.0	7 29.2 2.7 0.8	16 66.7 3.3 1.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	24 2.7
Other		1 9.1 1.1 0.1	0 0.0 0.0 0.0	1 9.1 100.0 0.1	2 18.2 0.8 0.2	7 63.6 1.5 0.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	11 1.2
	Column Total	90 10.2	14 1.6	1 0.1	256 28.9	482 54.4	27 3.0	14 1.6	2 0.2	886 100.0

TABLE 7.6.1. NUMBER OF RIDER VIOLATIONS LAST 2 YEARS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Violations	0.	325	36.1	38.6	38.6
	1.	217	24.1	25.8	64.4
	2.	129	14.3	15.3	79.8
	3.	68	7.6	8.1	87.9
	4.	38	4.2	4.5	92.4
	5.	23	2.6	2.7	95.1
	6.	14	1.6	1.7	96.8
7 Or More	7.	27	3.0	3.2	100.0
Unknown	8.	59	6.6	Missing	100.0
	TOTAL	900	100.0	100.0	

Number Of Rider Violations Last 2 Years, Fatals Only

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Violations	0.	15	27.8	32.6	32.6
	1.	13	24.1	28.3	60.9
	2.	4	7.4	8.7	69.6
	3.	3	5.6	6.5	76.1
	4.	6	11.1	13.0	89.1
	5.	2	3.7	4.3	93.5
	6.	1	1.9	2.2	95.7
7 Or More	7.	2	3.7	4.3	100.0
Unknown	8.	8	14.8	Missing	100.0
	TOTAL	54	100.0	100.0	

Table 7.6.2 shows the recent previous accident experience for the motorcycle riders involved in the 900 on-scene, in-depth accident cases. Also included is the accident experience for the 54 fatal cases within the 900 accidents.

Table 7.6.3 (Appendix C.3) is a crosstabulation of motorcycle rider license qualification and traffic violation experience.

Table 7.6.4 (Appendix C.3) shows a crosstabulation of motorcycle rider traffic violation and previous accident experience for the 900 accident cases. A condensation of Table 7.6.4 is as follows.

TABLE 7.6.2. NUMBER OF RIDER ACCIDENTS LAST 2 YEARS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Accidents	0.	587	65.2	69.2	69.2
	1.	200	22.2	23.6	92.8
	2.	41	4.6	4.8	97.6
	3.	18	2.0	2.1	99.8
	4.	2	0.2	0.2	100.0
Unknown	8.	52	5.8	Missing	100.0
	TOTAL	900	100.0	100.0	

Number Of Rider Accidents Last 2 Years, Fatals Only

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Accidents	0.	31	57.4	67.4	67.4
	1.	10	18.5	21.7	89.1
	2.	2	3.7	4.3	93.5
	3.	3	5.6	6.5	100.0
Unknown	8.	8	14.8	Missing	100.0
	TOTAL	54	100.0	100.0	

	Violations		
Accidents	None	1 - 7	Total
None	267	316	583
1 or more	58	198	256
TOTAL	325	514	839

For these accident-involved motorcycle riders, the traffic violation experience is shown to be the more critical association.

Table 7.6.5 (Appendix C.3) shows a crosstabulation of the traffic violation experience and accident precipitating factor for the 900 accident cases. A rearrangement of this tabulation separates the two most frequent accident precipitating factors:

Traffic Violation Experience	Accident Precipitating Factor: Motorcycle Rider Error	Accident Precipitating Factor: OV Violation of ROW
No previous violations	137	158
1 or more	200	275
2 or more	119	157
3 or more	63	91
TOTAL	(337)	(443)

In general, these data show that the motorcycle riders with no moving violations in the previous two years are more associated with accidents precipitated by motorcycle rider error.

Table 7.6.6 (Appendix C.3) shows a crosstabulation of accident experience with accident precipitating factor. A rearrangement of this tabulation separates the two most frequent accident precipitating factors.

Traffic Accident Experience	Accident Precipitating Factor: Motorcycle Rider Error	Accident Precipitating Factor: OV Violation of ROW
No previous accidents	246	291
1 or more	94	145
2 or more	20	36
3 or more	8	11
TOTAL	(340)	(436)

In general, these data show the tendency of previous accident involvement to be more associated with other vehicle culpability. An implication is either the dominant culpability of the other vehicle driver, or the failure of the accident-involved motorcycle rider to develop an effective traffic strategy.

7.7 Motorcycle Rider Training Experience

Table 7.7.1 shows the training (not) received by the 900 motorcycle riders in the multidisciplinary study. Those riders who had learned from family and friends, or who were self-taught, were 92.0% of the total. This represents a spectacular gap in the transfer of vital accident and injury information. Imagine one motorcycle rider learning anything valuable from another rider who has no appreciation of head and eye protection and no understanding of the vital performance of the front brake in collision avoidance. This situation is clearly the weak link in the development of defensive riding strategies and accident prevention.

Table 7.7.1 also shows the recommendations of those accident-involved riders to avoid or prevent accidents. Note that there were no recommendations in 52.0% of those cases, and it was apparent that those riders were (at that time) still confused about the accident circumstances and had not reconstructed those events for culpability. The very low recommendation for motorcycle safety courses and improved licensing is associated with the lack of perceived and actual culpability for the motorcycle rider. Education of the automobile drivers for awareness of motorcycles in traffic was suggested by 26.5%. In most cases of this response, punitive action was popular. Punitive action for culpable automobile drivers was a major part of the "other" recommendations, which were 14.2% of the total.

7.8 Motorcycle Rider Dirt Bike Experience

Table 7.8.1 shows that 28.6% of the motorcycle riders claimed significant experience on dirt bikes by recreational trail and desert riding. It is

TABLE 7.7.1. RIDER MOTORCYCLE TRAINING (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Self Taught	0.	400	44.4	49.5	49.5
Friends-Family	1.	343	38.1	42.5	92.0
Motorcycle Course	2.	41	4.6	5.1	97.0
By Professionals	3.	20	2.2	2.5	99.5
Other	4.	4	0.4	0.5	100.0
Unknown	8.	92	10.2	Missing	100.0
	TOTAL	900	100.0	100.0	

Rider Recommendations To Avoid Accidents (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	395	43.9	52.0	52.0
Education Of OV	1.	201	22.3	26.5	78.5
Motorcycle Licensing	2.	15	1.7	2.0	80.5
Motorcycle Safety Course	3.	40	4.4	5.3	85.8
Other	4.	108	12.0	14.2	100.0
Unknown	8.	141	15.7	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.8.1. RIDER DIRT BIKE EXPERIENCE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes	1.	238	26.4	28.6	28.6
No	2.	595	66.1	71.4	100.0
Unknown	8.	67	7.4	Missing	100.0
	TOTAL	900	100.0	100.0	

estimated that far less than half of these riders had any competition experience such as enduro, motorcross, scrambles, TT, desert, etc.

A popular proposition is that dirt bike experience prepares the motorcycle rider for hazardous traffic events, especially those relating to road hazards and vehicle problems. Table 7.8.2 shows the crosstabulation of rider dirt bike experience and vehicle involvement. These data show that the riders with dirt bike experience are only slightly underrepresented in the single vehicle collisions. The basic proposition would contend an advantage of high significance in reducing accidents due to loss of control, etc., and this advantage is not shown here.

TABLE 7.8.2 RIDER FIRST BIKE EXPERIENCE BY MULTIPLE/SINGLE VEHICLE (OSIDs)

Dirt Bike Experience	Count Row Pct Col Pct Tot Pct	Single Vehicle	Multi-Vehicle	Unknown	Row Total
Yes		48 20.2 23.1 5.3	176 73.9 26.6 19.6	14 5.9 45.2 1.6	238 26.4
No		141 23.7 67.8 15.7	439 73.8 66.4 48.8	15 2.5 48.4 1.7	595 66.1
Unknown		19 28.8 9.1 2.1	45 68.2 6.8 5.0	2 3.0 6.5 0.2	66 7.3
N/A		0 0.0 0.0 0.0	1 100.0 0.2 0.1	0 0.0 0.0 0.0	1 0.1
	Column Total	208 23.1	661 73.4	31 3.4	900 100.0

Table 7.8.3 shows the motorcycle rider dirt bike experience with the accident precipitating factor for the 900 accident cases. This table shows the motorcycle rider with dirt bike experience is slightly underrepresented in the accident cases involving motorcycle rider error and vehicle failure.

TABLE 7.8.3 RIDER DIRT BIKE EXPERIENCE BY ACCIDENT PRECIPITATING FACTOR (OSIDs)

Dirt Bike Experience	Count / Row Pct / Col Pct / Tot Pct	Factor: Phantom Vehicle	MC Error	OV Violation of MC ROW	Roadway Defect	Pedestrian	Animal	Vehicle Failure	Other	Unknown	Row Total
Yes		2	83	128	6	3	4	5	6	1	238
		0.8	34.9	53.8	2.5	1.3	1.7	2.1	2.5	0.4	26.4
		50.0	22.6	28.0	33.3	50.0	40.0	20.0	54.5	50.0	
		0.2	9.2	14.2	0.7	0.3	0.4	0.6	0.7	0.1	
No		1	249	300	11	3	6	20	5	0	595
		0.2	41.8	50.4	1.8	0.5	1.0	3.4	0.8	0.0	66.1
		25.0	67.8	65.6	61.1	50.0	60.0	80.0	45.5	0.0	
		0.1	27.7	33.3	1.2	0.3	0.7	2.2	0.6	0.0	
Unknown		1	34	29	1	0	0	0	0	1	66
		1.5	51.5	43.9	1.5	0.0	0.0	0.0	0.0	1.5	7.3
		25.0	9.3	6.3	5.6	0.0	0.0	0.0	0.0	50.0	
		0.1	3.8	3.2	0.1	0.0	0.0	0.0	0.0	0.1	
N/A		0	1	0	0	0	0	0	0	0	1
		0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
		0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
		0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Column Total	4	367	457	18	6	10	25	11	2	900
		0.4	40.8	50.8	2.0	0.7	1.1	2.8	1.2	0.2	100.0

7.9 Motorcycle Rider Street Bike Experience

Talbe 7.9.1 shows the days per week that the accident-involved rider rides motorcycles. Note that 56.5% of the riders claimed to ride all seven days per week, implying high utility of the motorcycle and depending upon the motorcycle as a major article of transportation. (Note: "0" was the code used when the accident-involved rider had not ridden previously, or had ridden only infrequently.)

TABLE 7.9.1. DAYS PER WEEK RIDER RIDES MOTORCYCLE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Days per Week	0.	61	6.8	7.4	7.4
	1.	33	3.7	4.0	11.3
	2.	45	5.0	5.4	16.8
	3.	54	6.0	6.5	23.3
	4.	43	4.8	5.2	28.5
	5.	86	9.6	10.4	38.8
	6.	39	4.3	4.7	43.5
	7.	468	52.0	56.5	100.0
Unknown	8.	68	7.6	Missing	100.0
N.A.	9.	3	0.3	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 7.9.2 (Appendix C.3) shows the months of street motorcycle riding experience claimed by the accident-involved rider. The median experience is approximately three years.

Table 7.9.3 (Appendix C.3) shows the months of experience on the accident-involved motorcycle by the rider. The median experience is approximately 5 months. Note the distinction between the total street motorcycle riding experience and the riding experience on the accident-involved motorcycle. In general, the median experience for total street motorcycle riding experience is almost 3 years, but the median experience on the accident-involved motorcycle is less than 5 months.

Table 7.9.4 has the experience data condensed in increments of experience for comparison.

TABLE 7.9.4 AMOUNT OF RIDER STREET MOTORCYCLE RIDING EXPERIENCE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
0-6 Months	1.	156	17.3	19.1	19.1
7-12 Months	2.	83	9.2	10.1	29.2
1-2 Years	3.	107	11.9	13.1	42.3
2-3 Years	4.	93	10.3	11.4	53.7
3-4 Years	5.	64	7.1	7.8	61.5
More Than 4 Years	6.	315	35.0	38.5	100.0
Unknown	8.	82	9.1	Missing	100.0
	TOTAL	900	100.0	100.0	
Experience On Accident-Involved Motorcycle (OSIDs)					
Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
0-6 Months	1.	491	54.6	57.4	57.4
7-12 Months	2.	136	15.1	15.9	73.3
1-2 Years	3.	112	12.4	13.1	86.4
2-3 Years	4.	63	7.0	7.4	93.8
3-4 Years	5.	26	2.9	3.0	96.8
More Than 4 Years	6.	27	3.0	3.2	100.0
Unknown	8.	45	5.0	Missing	100.0
	TOTAL	900	100.0	100.0	

Of course, there are special problems in obtaining accurate estimates of rider experience by personal interview. It would be an incredible situation for the accident-involved motorcycle rider to respond to the interview with "no, I don't know nuthin' about bikes; I've never ridden a motorcycle before in my whole life!" The more likely situation is that the rider tries to "shuck and jive" the interviewer with great reconstructions of dirt bike experience, racing experience, and the old Honda, BSA, or Harley he used to own. It was critical that the interviewer have his own considerable motorcycle experience to qualify the interview information. For these reasons, the experience in the accident-involved motorcycle is the more realistic measure of street motorcycle riding experience.

These data portray the accident-involved rider as not lacking in experience. Those motorcycle riders with 0 to 6 months street riding experience are only 19.1% of this accident population. Note that far more than one-third (38.5%) of the accident-involved motorcycle riders had more than 4 years experience. These riders have experience, but not on the accident-involved motorcycle.

A special contradiction shown here is that these motorcycle riders have experience, but no training.

7.10 Motorcycle Rider Familiarity with Roadway

Table 7.10.1 shows the number of times that the accident-involved motorcycle rider traversed that roadway at the accident site. The data are shown for the 900 on-scene, in-depth accident cases, and the 54 fatal accidents of that group.

While most cases show that the rider was familiar with the roadway, it is surprising that 10.3% of the accident cases involved a roadway which the rider had never traveled before.

7.11 Motorcycle Rider Hand Preference

The detailed interviews with the accident-involved motorcycle riders revealed that 10.8% were left-handed. This factor implies limitations of front as well as rear brake use during the emergency conditions of collision avoidance. Table 7.11.1 also shows that 3.8% of those accident involved motorcycle riders claimed to be ambidextrous.

7.12 Motorcycle Rider Alcohol and Drug Involvement

Table 7.12.1 shows the rider alcohol and drug involvement for the 900 on-scene, in-depth accident cases. A total of 11.5% of the accident-involved riders had some sort of involvement and some degree of impairment. Table 7.12.2 shows that alcohol and drug involvement for the 54 fatal accidents in the 900 cases. Of those fatal accidents, 40.9% involved rider impairment.

Tables 7.12.3 and 7.12.4 show the rider blood alcohol level at the time of the accident for the 900 on-scene, in-depth cases and the 54 fatal cases.

TABLE 7.10.1. RIDER FAMILIARITY WITH ROADWAY NUMBER OF TIMES RIDER TRAVERSED ROADWAY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
900 OSIDs				
Never Before	0.	85	9.4	10.3
Daily	1.	386	42.9	46.8
1-4 Times Weekly	2.	205	22.8	24.9
1-3 Times Monthly	3.	73	8.1	8.9
1-2 Times Quarterly	4.	20	2.2	2.4
1-3 Times Annually	5.	33	3.7	4.0
Less than Anually	6.	22	2.4	2.7
Unknown	8.	76	8.4	Missing
	TOTAL	900	100.0	100.0
OSID Fatals Only				
Never Before	0.	1	1.9	2.5
Daily	1.	20	37.0	50.0
1-4 Times Weekly	2.	8	14.8	20.0
1-3 Times Monthly	3.	3	5.6	7.5
1-2 Times Quarterly	4.	3	5.6	7.5
1-3 Times Annually	5.	3	5.6	7.5
Less than Annually	6.	2	3.7	5.0
Unknown	8.	14	25.9	Missing
	TOTAL	54	100.0	100.0

TABLE 7.11.1. RIDER HAND PREFERENCE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Right	1.	712	79.1	85.4
Left	2.	90	10.0	10.8
Ambidextrous	3.	32	3.6	3.8
Unknown	8.	66	7.3	Missing
	TOTAL	54	100.0	100.0

TABLE 7.12.1. RIDER ALCOHOL OR DRUG INVOLVEMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
HBD, Not Under Influence	1.	35	3.9	4.0	4.0
HBD, Under Influence	2.	37	4.1	4.2	8.2
HBD, Impairment Unknown	3.	23	2.6	2.6	10.8
Drug Influence	4.	3	0.3	0.3	11.1
Combination	5.	5	0.6	0.6	11.7
Unknown	8.	24	2.7	Missing	Missing
N.A.	9.	773	85.9	88.2	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.12.2. RIDER ALCOHOL OR DRUG INVOLVEMENT, FATAL ACCIDENTS ONLY (OSID FATALS ONLY)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
HBD, Not Under Influence	1.	7	13.0	13.7	13.7
HBD, Under Influence	2.	12	22.2	23.5	37.2
HBD, Impairment Unknown	3.	1	1.9	2.0	39.2
Drug Influence	4.	1	1.9	2.0	41.2
Combination	5.	1	1.9	2.0	43.1
Unknown	8.	3	5.6	Missing	Missing
N.A.	9.	29	53.7	56.9	100.0
	TOTAL	54	100.0	100.0	

TABLE 7.12.3. RIDER BLOOD ALCOHOL LEVEL AT TIME OF ACCIDENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Blood Alcohol Level, %	.00	776	86.2	94.6
	.01	1	0.1	0.1
	.02	1	0.1	0.1
	.03	3	0.3	0.4
	.04	1	0.1	0.1
	.05	2	0.2	0.2
	.06	1	0.1	0.1
	.07	2	0.2	0.2
	.08	3	0.3	0.4
	.09	1	0.1	0.1
	.10	4	0.4	0.5
	.11	2	0.2	0.2
Median of Alcohol Involved Riders →	.12	1	0.1	0.1
	.13	1	0.1	0.1
	.14	3	0.3	0.4
	.15	2	0.2	0.2
	.16	1	0.1	0.1
	.17	1	0.1	0.1
	.18	3	0.3	0.4
	.19	1	0.1	0.1
	.20	1	0.1	0.1
	.21	4	0.4	0.5
	.22	2	0.2	0.2
	.28	1	0.1	0.1
	.30	1	0.1	0.1
	.31	1	0.1	0.1
Unknown	.98	80	8.9	Missing
	TOTAL	900	100.0	100.0

TABLE 7.12.4. RIDER BLOOD ALCOHOL LEVEL AT TIME OF ACCIDENT (OSID FATALS ONLY)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Blood Alcohol, %	.00	29	53.7	59.2	59.2
	.02	1	1.9	2.0	61.2
	.03	2	3.7	4.1	65.3
	.05	1	1.9	2.0	67.3
	.07	1	1.9	2.0	69.4
	.08	1	1.9	2.0	71.4
	.09	1	1.9	2.0	73.5
	.11	2	3.7	4.1	77.6
Median Of Alcohol Involved Riders →	.12	1	1.9	2.0	79.6
	.13	1	1.9	2.0	81.6
	.14	1	1.9	2.0	83.7
	.15	1	1.9	2.0	85.7
	.19	1	1.9	2.0	87.8
	.21	3	5.6	6.1	93.9
	.22	1	1.9	2.0	95.9
	.30	1	1.9	2.0	98.0
	.31	1	1.9	2.0	100.0
Unknown	.98	5	9.3	Missing	100.0
	TOTAL	54	100.0	100.0	

The median value for the 900 cases is 0.125%, and the distribution of the 54 fatals has the same median value. In the fatal accident cases, the blood alcohol level was obtained from toxicological analysis; in the non-fatal cases, the blood alcohol level was taken from law enforcement test records when breath, blood or urine tests were made. When no such test record was available, calculations were performed based on drinks consumed, body weight, and elapsed time in order to have a suitable estimate.

Tables 7.12.5 and 7.12.6 shows the rider use of drugs other than alcohol and identifies the type of drug involved. The most frequent depressant involved was Quaalude.

Table 7.12.7 shows the rider alcohol involvement for the 3600 traffic accident reports analyzed. The circumstances of the accidents and the criteria for notation of alcohol involvement on the police traffic accident report relate an actual involvement higher than shown in this table. In comparing the same accident results, it was obvious that alcohol involvement was noted on the police traffic accident report only when the impairment was severe and sufficient for prosecution.

TABLE 7.12.5. RIDER USE OF DRUGS OTHER THAN ALCOHOL (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	811	90.1	95.9
Prescription	1.	18	2.0	2.1
Non-Prescription	2.	17	1.9	2.0
Unknown	8.	54	6.0	Missing
	TOTAL	900	100.0	100.0

Rider Use of Drugs--Type of Drug (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	810	90.0	96.2
Marijuana	1.	9	1.0	1.1
Stimulants	2.	2	0.2	0.2
Depressants	3.	15	1.7	1.8
Depressant Antihistamine	5.	3	0.3	0.4
Stimulant Antihistamine	6.	1	0.1	0.1
Multiple	7.	2	0.2	0.2
Unknown	8.	58	6.4	Missing
	TOTAL	900	100.0	100.0

TABLE 7.12.6. RIDER USE OF DRUGS OTHER THAN ALCOHOL
(OSID FATALS ONLY)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Prescription/Non-prescription status				
None,	0.	47	87.0	94.0
Prescription	1.	2	3.7	4.0
Non-Prescription	2.	1	1.9	2.0
Unknown	8.	4	7.4	Missing
	TOTAL	54	100.0	100.0
Type of Drug				
None	0.	47	87.0	94.0
Depressants	3.	2	3.7	4.0
Multiple	7.	1	1.9	2.0
Unknown	8.	4	7.4	Missing
	TOTAL	54	100.0	100.0

TABLE 7.12.7. RIDER ALCOHOL AND DRUG INVOLVEMENT (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Had Not Been Drinking	1.	3221	89.5	94.2	94.2
HBD-Influence Unk.	2.	187	5.2	5.5	99.6
Under Drug Influence	3.	12	0.3	0.4	100.0
Unknown/Not Reported	8.	180	5.0	Missing	100.0
	TOTAL	3600	100.0	100.0	

7.13 Motorcycle Rider Physiological Impairment

Table 7.13.1 shows the permanent physiological impairment of the accident-involved motorcycle riders. The specific items which deserve explanation are as follows:

Code 3. Brain (2) - Epileptics

Code 5. Vision (3) - Blind or missing one eye

Code 8. Loss of Limbs (1) - Lower left leg prosthesis as a result of an industrial accident

Code 9. Other (3) - Deaf (1) and Deaf Mute (2)

TABLE 7.13.1. RIDER PERMANENT PHYSIOLOGICAL IMPAIRMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	886	98.4	98.4
Diabetes	2.	2	0.2	0.2
Brain	3.	2	0.2	0.2
Cardio-Vascular	4.	3	0.3	0.3
Vision	5.	3	0.3	0.3
Loss Of Limbs	8.	1	0.1	0.1
Other	9.	3	0.3	0.3
	TOTAL	900	100.0	100.0

Table 7.13.2 shows the temporary physiological impairment for the accident-involved motorcycle riders. Fatigue and hunger predominated and required further investigation. Table 7.13.3 (Appendix C.3) provides a crosstabulation of this rider temporary physiological impairment with time riding before the accident. The two rider impairment conditions of fatigue and hunger are not

TABLE 7.13.2. RIDER TEMPORARY PHYSIOLOGICAL IMPAIRMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	826	91.8	91.8
Fatigue	1.	20	2.2	2.2
Hunger	2.	20	2.2	2.2
Thirst	3.	2	0.2	0.2
Siesta Syndrome	4.	1	0.1	0.1
Elimination Urgency	5.	3	0.3	0.3
Minor Malaise	6.	3	0.3	0.3
Other or Unknown	8.	25	2.8	2.8
	TOTAL	900	100.0	100.0

related to the effects of the motorcycle riding tasks, helmet use, etc. Ninety percent of those two conditions are noted to occur within 0.5 hours of riding time and are clearly pre-existing conditions.

7.14 Motorcycle Rider Characteristics, Tattoos

The tattoo is the traditional mark of the person with risk-taking tendencies, and the number of tattoos was recorded as human factors data for each of the accident cases.

Table 7.14.1 shows the tattoos for all accidents (900) and the fatal accidents of that group (54).

Table 7.14.2 shows the tattoos for the accompanying passengers who were involved in the accidents.

7.15 Motorcycle Rider Performance, Rider Attention to Driving Task

Table 7.15.1 relates the rider attention to the driving task in the pre-crash events. Adjacent traffic, non-traffic items, and motorcycle operation held the attention of riders in 21.8% of the 900 on-scene, in-depth accident cases. The motorcycle rider was in the inattentive mode in 19.1% of the cases. This total of 40.9% of the cases depicts a significant contribution of distraction and inattention in the pre-crash events. Motorcycle safety training can focus on this problem by developing skills and traffic strategy to concentrate attention to the tasks of traffic.

Also, Section 6.11 portrays the greatest part of the accident hazards in the line-of-sight of 11, 12 and 1 o'clock. In other words, the requirements for rider attention to the driving task are completely conventional in orientation. There are no special attention requirements in the lateral spaces.

TABLE 7.14.1. MOTORCYCLE RIDER BODY TATTOOS (900 OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Tattoos	0.	631	70.1	80.0
	1.	75	8.3	9.5
	2.	43	4.8	5.4
	3.	15	1.7	1.9
	4.	8	0.9	1.0
	5.	2	0.2	0.3
	6.	4	0.4	0.5
7 Or More	7.	11	1.2	1.4
Unknown	8.	111	12.3	Missing
	TOTAL	900	100.0	100.0

(54 Fatals Only)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Tattoos	0.	38	70.4	71.7
	1.	6	11.1	11.3
	2.	3	5.6	5.7
	3.	2	3.7	3.8
	4.	1	1.9	1.9
	5.	1	1.9	1.9
	6.	1	1.9	1.9
7 Or More	7.	1	1.9	1.9
Unknown	8.	1	1.9	Missing
	TOTAL	54	100.0	100.0

TABLE 7.14.2. BODY TATTOOS-PASSENGER (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Tattoos	0.	87	9.7	88.8
	1.	4	0.4	4.1
	2.	3	0.3	3.1
	3.	1	0.1	1.0
	4.	1	0.1	1.0
	6.	1	0.1	1.0
7 Or More	7.	1	0.1	1.0
Unknown	8.	54	6.0	Missing
N.A.	9.	748	83.1	Missing
	TOTAL	900	100.0	

TABLE 7.15.1. RIDER ATTENTION TO DRIVING TASK (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Attention diverted to surrounding traffic	1.	106	11.8	12.6	12.6
Attention diverted to non-traffic item	2.	43	4.8	5.1	17.7
Attention diverted to motorcycle operation	3.	35	3.9	4.2	21.8
Inattentive Mode	4.	161	17.9	19.1	40.9
Unknown	8.	57	6.3	Missing	Missing
N.A. Attention to driving task not a factor	9.	498	55.3	59.1	100.0
	TOTAL	900	100.0	100.0	

7.16 Motorcycle Rider Performance, Rider Stress on Day of Accident

Table 7.16.1 shows the type of stress which was detectable by the research personnel during the 900 on-scene, in-depth investigations. The outstanding factor contributing to rider stress which was observed was due to conflict with relatives and close friends, who were members of the immediate household. The second most significant factor was that stress related to some special beneficial event which generated pressure affecting events of the day, e.g., promotion, new motorcycle, etc. These stresses were in fact related to those motorcycle riders being inattentive during the precrash time.

TABLE 7.16.1. RIDER STRESS-DAY OF ACCIDENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	781	86.8	86.8
Relatives Conflict	1.	38	4.2	4.2
Work Conflict	2.	4	0.4	0.4
Death, Illness	3.	3	0.3	0.3
Financial	4.	9	1.0	1.0
School, Work	5.	17	1.9	1.9
Legal, Police	6.	14	1.6	1.6
Social Agency	7.	1	0.1	0.1
Reward	8.	33	3.7	3.7
	TOTAL	900	100.0	100.0

7.17 Motorcycle Rider Collision Avoidance Performance

Of course, the collision avoidance performance of an accident-involved motorcycle rider is expected to show problems and failures. Each one of the 900 on-scene, in-depth accident cases was completely reconstructed to provide all details of the precrash events. The motorcycle rider's precrash actions were determined and evaluated to determine the collision avoidance performance.

One of the most critical factors in reconstructing the sequence of precrash events is the chronology of those events. The speeds, accelerations, distances and directions were determined in each case and the time available for collision avoidance was determined. The time available to the motorcycle rider for collision avoidance begins with the initiation of the precipitating event and terminates with the crash impact. For example, an automobile in traffic approaching the motorcycle path begins a left turn in front of the oncoming motorcycle, the rider later detects that motion, decides on rear braking, applies the rear brake and skids into the left-turning automobile. That total time from the automobile beginning the left turn until crash impact is derived for each of the 900 on-scene, in-depth investigations.

Table 7.17.1 shows that time available for collision avoidance for all 900 cases. The median value is less than 1.9 seconds. It is typical that the motorcycle rider must detect, decide and react to a traffic hazard in less than two seconds. Any significant delay in the hazard detection, decision and control action will preclude success of the collision avoidance.

Consider that typical case specified where the automobile turns left in front of the oncoming motorcycle. If the motorcycle initial speed is 35 mph, an attainable braking distance is 50' if both front and rear brakes are used well. If the rider requires 1 second total reaction time for detection, decision and neuromuscular and vehicle reaction, then a total of 3 seconds and 100' are required for a safe stop. The fundamental problem is a serious lack of time for success in collision avoidance; two seconds are available but three seconds are required. The proper evasive action must be taken and executed well without any delay.

But the accident-involved motorcycle riders made errors of the collision avoidance action and execution. Table 7.17.2 shows the evasive action taken by the rider and evaluates the execution and choice of action. Within the data shown are several basic problems. Emergency braking skills are required for success in collision avoidance maneuvers, however both brakes were used in only 17.0% of the accidents (and many times not used well). The most common action was to use the rear brake only (18.5%) or the rear brake and swerve (11.7%). This failure to use the front brake is a critical element in collision avoidance because proper use of the front brake would have avoided many of the collisions or greatly reduced the severity.

The execution of the evasive action was correct in 15.6% of the accident cases, or 23.8% of the time some evasive action was attempted. A typical problem would be as follows: An oncoming automobile turns left in front of the motorcycle; the rider locks up the rear wheel by overbraking, slides out and falls to the roadway, and slides into the automobile. Another example would be as follows: with a violation of his right-of-way, the motorcycle rider

TABLE 7.17.1. TIME FROM PRECIPITATING EVENT TO IMPACT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cummulative Frequency (%)
Time, seconds	0.0	1	0.1	0.1	0.1
	0.1	1	0.1	0.1	0.2
	0.2	1	0.1	0.1	0.4
	0.4	4	0.4	0.5	0.9
	0.5	4	0.4	0.5	1.3
	0.6	1	0.1	0.1	1.5
	0.7	12	1.3	1.5	2.9
	0.8	7	0.8	0.9	3.8
	0.9	1	0.1	0.1	3.9
	1.0	22	2.4	2.7	6.6
	1.1	5	0.6	0.6	7.2
	1.2	31	3.4	3.8	11.0
	1.3	36	4.0	4.4	15.4
	1.4	44	4.9	5.4	20.8
	1.5	53	5.9	6.5	27.3
	1.6	62	6.9	7.6	34.9
	1.7	41	4.6	5.0	39.9
	1.8	67	7.4	8.2	48.1
	1.9	29	3.2	3.5	51.7
	2.0	79	8.8	9.7	61.3
	2.1	31	3.4	3.8	65.1
	2.2	53	5.9	6.5	71.6
	2.3	27	3.0	3.3	74.9
	2.4	23	2.6	2.8	77.7
	2.5	42	4.7	5.1	82.9
	2.6	18	2.0	2.2	85.1
	2.7	12	1.3	1.5	86.5
	2.8	20	2.2	2.4	89.0
	2.9	7	0.8	0.9	89.8
	3.0	27	3.0	3.3	93.1
	3.1	10	1.1	1.2	94.4
	3.2	14	1.6	1.7	96.1
	3.3	1	0.1	0.1	96.2
	3.4	4	0.4	0.5	96.7
	3.5	8	0.9	1.0	97.7
	3.6	1	0.1	0.1	97.8
	3.7	3	0.3	0.4	98.2
	3.8	5	0.6	0.6	98.8
	4.0	3	0.3	0.4	99.1
	4.1	1	0.1	0.1	99.3
	4.4	1	0.1	0.1	99.4
	4.9	1	0.1	0.1	99.5
	5.1	1	0.1	0.1	99.6
	5.2	1	0.1	0.1	99.8
	6.0	2	0.2	0.2	100.0
Unknown	9.8	77	8.6	Missing	100.0
N.A.	9.9	6	0.7	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.17.2. MOTORCYCLE EVASIVE ACTION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Evasive Action Taken				
None	0.	283	31.4	31.9
Rear Brake Only	1.	164	18.2	18.5
Front Brake Only	2.	7	0.8	0.8
Both Brakes	3.	151	16.8	17.0
Swerve Only	4.	74	8.2	8.4
Lay Down & Slide	5.	8	0.9	0.9
Accelerate	6.	8	0.9	0.9
Rear Brake & Swerve	7.	104	11.6	11.7
Front Brake & Swerve	8.	4	0.4	0.5
Both Brakes & Swerve	9.	77	8.6	8.7
Accelerate & Swerve	10.	1	0.1	0.1
Other	12.	5	0.6	0.6
Unknown	98.	14	1.6	Missing
	TOTAL	900	100.0	100.0
Evasive Action Properly Executed?				
Yes	1.	140	15.6	23.8
No	2.	449	49.9	76.2
Unknown	8.	14	1.6	Missing
N.A.	9.	297	33.0	Missing
	TOTAL	900	100.0	100.0
Evasive Action Proper for Situation?				
Yes	1.	263	29.2	43.7
Probable	2.	7	0.8	1.2
Undecided	3.	1	0.1	0.2
Improbable	4.	4	0.4	0.7
No	5.	327	36.3	54.3
Unknown	8.	9	1.0	Missing
N.A.	9.	289	32.1	Missing
	TOTAL	900	100.0	100.0

applies both brakes, overbrakes at the front, locks up the front wheel, slides out and falls to the roadway. Skidding from overbraking was the most common execution problem, and usually resulted in a loss of control of the motorcycle. Many accident-involved riders would describe their pre-crash action as "laying the bike down" to avoid the crash, when in reality the accident evidence pointed to a simple case of overbraking at the rear wheel, slide out and fall with a complete loss of control by the rider. A controlled "lay down and slide" was verified in only 8 accident cases and in fact was the wrong choice of evasive action in 6 of those 8 cases.

In the pre-crash actions shown in Table 7.17.2, it is seen that the accident-involved rider demonstrates poor choice of evasive action and executes that choice poorly. Overbraking at the rear wheel and underbraking at the front wheel is a common combination of errors. But foremost in these data is the fact that <u>31.9% of the riders did NOTHING</u> in the way of evasive action in the precrash time.

Table 7.17.3 provides a crosstabulation of collision avoidance action and the evaluation of that choice of action. Note that the use of the rear brake only was a very poor choice, as were most of the decisions made by the accident-involved riders.

Table 7.17.4 evaluates the execution of the chosen collision avoidance action. Most of the execution failures in braking involved skidding, particularly for the rear wheel since it was utilized the most often. The attempts to swerve were very badly executed, with most failures illustrating no concise collision avoidance capability of the accident-involved rider. The ability to intentionally counter-steer and generate the sudden swerve was generally unknown by these riders.

These data are not intended to substantiate any need for high speed, high performance rider training as a countermeasure in accident prevention. However, they show that these accident-involved riders did not demonstrate some <u>basic</u> motorcycle riding skills in that instant when a hazard was presented.

For comparison, the motorcycle rider was asked about his own braking habits, and in particular, the frequency of front brake use. Table 7.17.5 shows the accident-involved rider's utilization of the front brake, which is <u>far greater</u> than that shown in the analysis of the accident events. Those riders state that they "usually" or "always" use the front brake a total of 73.5% of the time. This would indicate relatively high use of the front brake and an expectation of the motorcycle to have acceptable stopping performance. The data shown previously in Tables 7.17.2, 7.17.3, and 7.17.4 regarding front brake use did <u>not</u> rely upon rider opinion or statement. Suspension displacements, control positions, skid patches, skidmarks, tire circumferential striations, etc., were analyzed by the research team to distinguish the <u>actual</u> function of the front brake to provide these data.

Regardless of the circumstances, the accident-involved rider is most likely to reconstruct the accident events without qualification or objectivity and respond affirmatively. Such opinions regarding brake use must not be considered factual.

TABLE 7.17.3. MOTORCYCLE EVASIVE ACTION TYPE BY PROPRIETY OF EVASIVE ACTION (OSIDs)

Evasive Action	Count / Row Pct / Col Pct / Tot Pct	Proper Evasive Action? Yes	Probable	Undecided	Improbable	No	Unknown	N/A	Row Total
None		4	0	0	0	3	0	276	283
		1.4	0.0	0.0	0.0	1.1	0.0	97.5	31.4
		1.5	0.0	0.0	0.0	0.9	0.0	95.5	
		0.4	0.0	0.0	0.0	0.3	0.0	30.7	
Rear Brake		15	2	1	1	142	0	3	164
		9.1	1.2	0.6	0.6	86.6	0.0	1.8	18.2
		5.7	28.6	100.0	25.0	43.4	0.0	1.0	
		1.7	0.2	0.1	0.1	15.8	0.0	0.3	
Front Brake		2	1	0	0	3	0	1	7
		28.6	14.3	0.0	0.0	42.9	0.0	14.3	0.8
		0.8	14.3	0.0	0.0	0.9	0.0	0.3	
		0.2	0.1	0.0	0.0	0.3	0.0	0.1	
Both Brakes		125	2	0	1	21	0	2	151
		82.8	1.3	0.0	0.7	13.9	0.0	1.3	16.8
		47.5	28.6	0.0	25.0	6.4	0.0	0.7	
		13.9	0.2	0.0	0.1	2.3	0.0	0.2	
Swerve		23	2	0	1	47	0	1	74
		31.1	2.7	0.0	1.4	63.5	0.0	1.4	8.2
		8.7	28.6	0.0	25.0	14.4	0.0	0.3	
		2.6	0.2	0.0	0.1	5.2	0.0	0.1	
Lay Down-Slide		2	0	0	0	6	0	0	8
		25.0	0.0	0.0	0.0	75.0	0.0	0.0	0.9
		0.8	0.0	0.0	0.0	1.8	0.0	0.0	
		0.2	0.0	0.0	0.0	0.7	0.0	0.0	
Accelerate		5	0	0	0	3	0	0	8
		62.5	0.0	0.0	0.0	37.5	0.0	0.0	0.9
		1.9	0.0	0.0	0.0	0.9	0.0	0.0	
		0.6	0.0	0.0	0.0	0.3	0.0	0.0	
1 and 4		12	0	0	0	92	0	0	104
		11.5	0.0	0.0	0.0	88.5	0.0	0.0	
		4.6	0.0	0.0	0.0	28.1	0.0	0.0	
		1.3	0.0	0.0	0.0	10.2	0.0	0.0	
2 and 4		0	0	0	0	4	0	0	4
		0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.4
		0.0	0.0	0.0	0.0	1.2	0.0	0.0	
		0.0	0.0	0.0	0.0	0.4	0.0	0.0	
3 and 4		71	0	0	0	4	0	0	77
		92.2	0.0	0.0	0.0	5.2	0.0	2.6	8.6
		27.0	0.0	0.0	0.0	1.2	0.0	0.7	
		7.9	0.0	0.0	0.0	0.4	0.0	0.2	
4 and 6		0	0	0	0	1	0	0	1
		0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.1
		0.0	0.0	0.0	0.0	0.3	0.0	0.0	
		0.0	0.0	0.0	0.0	0.1	0.0	0.0	
Other		3	0	0	1	1	0	0	5
		60.0	0.0	0.0	20.0	20.0	0.0	0.0	0.6
		1.1	0.0	0.0	25.0	0.3	0.0	0.0	
		0.3	0.0	0.0	0.1	0.1	0.0	0.0	
Unknown		1	0	0	0	0	9	4	14
		7.1	0.0	0.0	0.0	0.0	64.3	28.6	1.6
		0.4	0.0	0.0	0.0	0.0	100.0	1.4	
		0.1	0.0	0.0	0.0	0.0	1.0	0.4	
	Column Total	263	7	1	4	327	9	289	900
		29.2	0.8	0.1	0.4	36.3	1.0	32.0	100.0

TABLE 7.17.4. MOTORCYCLE EVASIVE ACTION TYPE BY PROPER EXECUTION OF EVASIVE ACTION (OSIDs)

Evasive Action	Count Row Pct Col Pct Tot Pct	Properly Executed? Yes	No	Unknown	N/A	Row Total
None		4 1.4 2.9 0.4	1 0.4 0.2 0.1	0 0.0 0.0 0.0	278 98.2 93.6 30.9	283 31.4
Rear Brake		22 13.4 15.7 2.4	134 81.7 29.8 14.9	3 1.8 21.4 0.3	5 3.0 1.7 0.6	164 18.2
Front Brake		1 14.3 0.7 0.1	5 71.4 1.1 0.6	0 0.0 0.0 0.0	1 14.3 0.3 0.1	7 0.8
Both Brakes		48 31.8 34.3 5.3	98 64.9 21.8 10.9	2 1.3 14.3 0.2	3 2.0 1.0 0.3	151 16.8
Swerve		8 10.8 5.7 0.9	65 87.8 14.5 7.2	0 0.0 0.0 0.0	1 1.4 0.3 0.1	74 8.2
Lay Down-Slide		7 87.5 5.0 0.8	1 12.5 0.2 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	8 0.9
Accelerate		4 50.0 2.9 0.4	2 25.0 0.4 0.2	0 0.0 0.0 0.0	2 25.0 0.7 0.2	8 0.9
1 and 4		10 9.6 7.1 1.1	93 89.4 20.7 10.3	0 0.0 0.0 0.0	1 1.0 0.3 0.1	104 11.6
2 and 4		0 0.0 0.0 0.0	4 100.0 0.9 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	4 0.4
3 and 4		32 41.6 22.9 3.6	43 55.8 9.6 4.8	0 0.0 0.0 0.0	2 2.6 0.7 0.2	77 8.6
4 and 6		0 0.0 0.0 0.0	1 100.0 0.2 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.1
Other		3 60.0 2.1 0.3	2 40.0 0.4 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 0.6
Unknown		1 7.1 0.7 0.1	0 0.0 0.0 0.0	9 64.3 64.3 1.0	4 28.6 1.3 0.4	14 1.6
	Column Total	140 15.6	449 49.9	14 1.6	297 33.0	900 100.0

TABLE 2.17.5. FREQUENCY OF FRONT BRAKE USE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Never	0.	23	2.6	3.3
Sometimes	1.	159	17.7	23.1
Usually	2.	192	21.3	27.9
Always	3.	314	34.9	45.6
Unknown	8.	180	20.0	Missing
N.A.	9.	32	3.6	Missing
	TOTAL	900	100.0	100.0

The precrash phase of an accident is an environment where very basic human reactions take place. In addition, the great majority of motorcycle riders have not had effective or regular training which prepares them for collision avoidance actions. Consequently, the precrash performance of most motorcycle riders will relate some very basic human factors problems.

Table 7.17.6 shows the collision avoidance action taken by the driver of the other vehicle involved in collision with the motorcycle. More than two-thirds (68.9%) did nothing. In great part, this situation is explainable by the detection failure, where the driver of the other vehicle "did not see the motorcycle", or "did not see it until it was too late".

TABLE 7.17.6. EVASIVE ACTION TAKEN BY OTHER VEHICLE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	472	52.4	68.9
Braking	1.	159	17.7	23.2
Steering	2.	4	0.4	0.6
1 and 2	3.	29	3.2	4.2
Accelerate	4.	18	2.0	2.6
Accelerate and Steer	5.	3	0.3	0.4
Unknown	8.	15	1.7	Missing
N.A.	9.	200	22.2	Missing
	TOTAL	900	100.0	100.0

Table 7.17.7 compares front brake use and rear brake use for the precrash time of the 900 in-depth accident cases. Reconstruction of the accident events was made by analysis of skid marks, tire tread circumferential striations, control positions, tire impact transfers, suspension displacements, and injury mechanisms for control associated limbs. These factors determined the function

TABLE 7.17.7. MOTORCYCLE REAR BRAKE OPERATION BY FRONT BRAKE OPERATION (OSIDs)

Rear Brake	Count / Row Pct / Col Pct / Tot Pct	Front Brake: Not Equipped	Equip., Not Oper	Oper, Not On	On at Accident	Equip., Not Known	Unknown if On	Row Total
Not Equipped		1 100.0 4.0 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.1
Equip., Not Oper		0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 20.0 0.2 0.1	4 80.0 1.7 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 0.6
Oper, Not On		11 3.1 44.0 1.2	14 3.9 38.9 1.6	322 90.2 57.1 35.9	8 2.2 3.4 0.9	2 0.6 40.0 0.2	0 0.0 0.0 0.0	357 39.8
On at Accident		13 2.5 52.0 1.5	22 4.3 61.1 2.5	239 46.8 42.4 26.7	222 43.4 94.9 24.8	1 0.2 20.0 0.1	14 2.7 43.8 1.6	511 57.0
Unknown if On		0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 9.1 0.4 0.2	0 0.0 0.0 0.0	2 9.1 40.0 0.2	18 81.8 56.3 2.0	22 2.5
	Column Total	25 2.8	36 4.0	564 62.9	234 26.1	5 0.6	32 3.6	896 100.0

and operation of the front and rear brakes in these precrash conditions. The rear brake was not equipped or not operational for 0.7% of the accident involved motorcycles. The rear brake was used in 57.0% of the accidents.

The front brake was not equipped or not operational for 6.8% of the accident involved motorcycles. The front brake was used in 26.1% of the accidents.

The data relate to the one special problem of braking for collision avoidance; the motorcycle riders in these accidents <u>underbrake at the front wheel</u> and <u>usually overbrake at the rear wheel</u>. The result is an inability to develop contemporary standards of emergency deceleration and collision avoidance. A vulnerability for accident involvement is sure to be the result.

The deficient collision avoidance braking performance has some obvious remedies. Bonafide experience in collision avoidance braking is rare for most street motorcycle riders. Such experience may be beneficial to develop and improve front wheel brake use and reduce rear wheel overbraking control problems. In addition, rider technique and strategy can be improved to enhance collision avoidance braking performance. Experienced riders usually ride in traffic with a couple of fingers already extended to the front brake lever. The reaction time for front brake use is reduced and the utility of front wheel braking is increased. High stress and panic reactions are predominantly

contraction. Thus, extending the fingers to the lever in precrash time requires training and conditioning and is not the untrained typical performance, i.e., the rider would typically grip the throttle more tightly. If the fingers are already extended to the lever, the contraction reaction is natural and typical.

Antilock or antiskid braking systems have the potential of eliminating control problems from front or rear wheel overbraking, and perhaps promoting front wheel brake use. The greatest part of these accidents occurred on dry, high friction surfaces so the advantage of antilock or antiskid would be elimination of control problems and restoring deceleration on high friction surfaces. Of course, the benefits for low friction surfaces would be available but those environmental conditions are not highly associated with accidents.

Interconnected front and rear brakes for simultaneous operation by a single control may be an advantage in collision avoidance conditions. However, most riders seem to prefer the individual controls for ordinary operation. The Moto Guzzi T-3 brake system is the only system available for study in these data. It would be useful if some additional future analysis could distinguish any advantage for that interconnected T-3 brake system of the Moto Guzzi. However, that equipment is of very low representation in these data, and that fact alone may be significant!

The obvious remedy for poor braking performance in collision avoidance action is either experience or training. The data for the 900 on-scene, in-depth accident cases were separated for various levels of motorcycle street experience and various training received by the rider. Tables 7.17.8 (Appendix C.3) through 7.17.13 (Appendix C.3) portray the various experience levels. Tables 7.17.14 (Appendix C.3) through 7.17.18 (Appendix C.3) portray the various training received by the riders.

Table 7.17.19 summarizes the rider use of the brakes in collision avoidance maneuvers. Front brake use increases with experience, except at high experience levels. Generally the same impression is accurate for rear brake use. Combined front and rear brake use also increases with experience, except at high experience levels. The benefits of training received by these accident-involved riders is not clear, because no favorable brake use patterns appear for the few trained riders.

Table 7.17.20 shows the precrash control operations for the 900 accident cases.

Table 7.17.21 shows an evaluation to determine if those precrash control operations interfered with collision avoidance action.

Table 7.17.22 (Appendix C.3) is a crosstabulation of these data to distinguish the interfering activities involved with accelerating and turning. In these cases, the accelerating actions preceded a possible demand for braking and the turning actions preceded a need for braking or reversal of turn for collision avoidance.

TABLE 7.17.19. PERCENT OF BRAKE USE BY RIDER IN COLLISION AVOIDANCE ACTION

Experience

Brake Use	All Levels	0-6 Months	7-12 Months	1-2 Years	2-3 Years	3-4 Years	More Than 4 Years
Front	26.1	20.5	28.9	31.8	32.3	34.4	26.6
Rear	57.0	50.6	67.5	63.6	60.2	64.1	58.7
Front & Rear	24.8	17.9	27.7	29.9	32.3	32.8	25.3
Total Cases	896	156	83	107	93	64	312

Training

Brake Use	All Training	Self Taught	Friends/ Family	Motorcycle Course	Professional	Other	Motorcycle + Professional + Other
Front	26.1	29.6	24.3	29.3	25.0	25.0	27.7
Rear	57.0	59.4	58.2	56.1	55.0	100.0	58.5
Front & Rear	24.8	27.8	23.4	26.8	25.0	25.0	26.2
Total Cases	896	399	342	41	20	4	65

TABLE 7.17.20. MOTORCYCLE PRECRASH CONTROL OPERATIONS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	379	42.1	45.0
Accelerating	1.	218	24.2	25.9
Downshifting	2.	61	6.8	7.2
Braking	3.	49	5.4	5.8
Fuel Adjustment	4.	6	0.7	0.7
Throttle Change	5.	29	3.2	3.4
Turning	7.	99	11.0	11.8
Other	9.	1	0.1	0.1
Unknown	98.	58	6.4	Missing
	TOTAL	900	100.0	100.0

TABLE 7.17.21. DID CONTROL OPERATIONS INTERFERE?

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Yes	1.	60	6.7	11.7
No	2.	447	49.7	87.1
Possibly	3.	6	0.7	1.2
Unknown	8.	64	7.1	Missing
N.A.	9.	323	35.9	Missing
	TOTAL	900	100.0	100.0

7.18 Motorcycle Rider Loss of Control

Table 7.18.1 shows the frequency of the rider loss of control. A great part of these primary (rider) control failures occurred in single vehicle accidents.

TABLE 7.18.1. LOSS OF CONTROL MODE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Capsize	1.	42	4.7	11.8
Wobble	2.	5	0.6	1.4
Weave	3.	2	0.2	0.6
Lost Wheelie	4.	9	1.0	2.5
Slide Out	5.	202	22.4	56.6
High Side	6.	19	2.1	5.3
Wide On Turn	7.	77	8.6	21.6
End Over	8.	1	0.1	0.3
Unknown	98.	4	0.4	Missing
N.A.	99.	539	59.9	Missing
	TOTAL	900	100.0	100.0

Table 7.18.2 shows the occurrences of these control problems in the single and multiple vehicle collisions.

The loss of control by capsize (11.8%) usually occurred after collision contact with another vehicle, a fixed object, or animal.

The wobble loss of control (1.4%) was that unstable oscillatory motion of the motorcycle front mass. These cases were a result of defective repair of a previously damaged motorcycle or modification with improperly installed accessories.

TABLE 7.18.2. LOSS OF CONTROL MODE BY SINGLE/MULTIPLE VEHICLE ACCIDENT (OSIDs)

Count Row Pct Col Pct Tot Pct	Single-Vehicle Collision	Multi-Vehicle Collision	Row Total
Capsize	19 45.2 9.0 5.4	23 54.8 16.0 6.5	42 11.8
Wobble	5 100.0 2.4 1.4	0 0.0 0.0 0.0	5 1.4
Weave	2 100.0 0.9 0.6	0 0.0 0.0 0.0	2 0.6
Lost Wheelie	7 77.8 3.3 2.0	2 22.2 1.4 0.6	9 2.5
Slide Out	113 56.4 53.6 31.8	87 43.5 60.4 24.5	200 56.3
High Side	12 63.2 5.7 3.4	7 36.8 4.9 2.0	19 5.4
Wide on Turn	52 67.5 24.6 14.6	25 32.5 17.4 7.0	77 21.7
End Over	1 100.0 0.5 0.3	0 0.0 0.0 0.0	1 0.3
Column Total	211 59.4	144 40.6	355 100.0

The weave loss of control (0.6%) cases were not associated with high speed but were associated with puncture flats and resultant loss of rear tire side force stiffness.

The lost wheelie was simple to detect in some cases and difficult in others. One simple case involved the tread print of a Dunlop F-6 front tire on an alley fence beginning 44" above the road surface. Another, more complex case, was first described by the rider of a high performance 750cc bike as a "high speed wobble". However, factual investigation uncovered a first gear wheelie from an intersection stop, shift to second continuing to lift the front wheel, then in third gear, the front wheel dropped crooked onto the roadway at 80 mph.

No fundamental lateral-directional dynamic problems of vehicle design were present in these loss of control accidents. Of course, vehicle speeds in these accidents were generally far below the very high speeds necessary to generate the classical lateral-directional stability problems.

The slide out and high side loss of control were generally associated with errors of braking, usually overbraking and skidding of the rear wheel. The total of 61.9% represents this factor as the most typical problem in loss of control. The accident-involved motorcycle riders contributed much to their own accident participation by these serious errors then loss of control.

Running wide on a turn was involved in 21.6% of the loss of control problems and was usually related to excess speed entering a turn and under-cornering in that turn rather than sliding out. Most cases of running wide on a turn were single vehicle accidents where the motorcycle ran off the road then collided with some parts of that environment. Other cases involved the motorcycle running wide on a turn and crossing into other traffic and colliding with an oncoming vehicle.

Table 7.18.3 shows the effect of motorcycle rider training for these accidents involving loss of control. Note that those motorcycle riders without significant training were 91.6% of this group (52.9% self-taught and 38.7% taught by friends-family). One special feature of these data is that all of the lost wheelies and weaves were accounted for by these untrained riders. Also, most of the losses of control by running wide on a turn (97.0%) were attributable to these untrained riders. Unfortunately, significant training does not show the same advantage in the most frequent loss of control, the slide out, where the untrained riders account for only their fair share of those accidents (92.0%).

Table 7.18.4 shows the effect of motorcycle rider experience for these accidents involving loss of control. Generally these data show no distinction for high or low experience, and even though the inexperienced rider appears over-represented on running wide on a turn, the quantity is not statistically significant.

Investigator opinions in the analysis of these loss of control accidents provided some additional insight into the problems. Those riders involved in slide out loss of control invariably appeared to have no skill or knowledge

TABLE 7.18.3. MOTORCYCLE RIDER TRAINING VERSUS LOSS OF CONTROL MODE (OSIDs)

Count Row Pct Col Pct Tot Pct	Self Taught	Friends-Family	MC Course	By Professionals	Other	Row Total
Capsize	15 44.1 8.8 4.6	14 41.2 11.2 4.3	3 8.8 17.6 0.9	2 5.9 22.2 0.6	0 0.0 0.0 0.0	34 10.5
Wobble	1 20.0 0.6 0.3	2 40.0 1.6 0.6	1 20.0 5.9 0.3	1 20.0 11.1 0.3	0 0.0 0.0 0.0	5 1.5
Weave	2 100.0 1.2 0.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.6
Lost Wheelie	5 55.6 2.9 1.5	4 44.4 3.2 1.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	9 2.8
Slide Out	98 52.4 57.3 30.3	74 39.6 59.2 22.9	8 4.3 47.1 2.5	6 3.2 66.7 1.9	1 0.5 100.0 0.3	187 57.9
High Side	10 55.6 5.8 3.1	5 27.8 4.0 1.5	3 16.7 17.6 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	18 5.6
Wide On Turn	40 59.7 23.4	25 37.3 20.0	2 3.0 11.8	0 0.0 0.0	0 0.0 0.0	67 20.7
End Over	0 0.0 0.0 0.0	1 100.0 0.8 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.3
Column Total	171 52.9	125 38.7	17 5.3	9 2.8	1 0.3	323 100.0

TABLE 7.18.4. RIDER EXPERIENCE ON ACCIDENT INVOLVED MOTORCYCLE BY LOSS OF CONTROL MODE

Count Row Pct Col Pct Tot Pct	Experience						
	0-6 Months	7-12 Months	1-2 Years	2-3 Years	3-4 Years	More Than 4 Years	Row Total
Capsize	23	7	7	1	0	2	40
	57.5	17.5	17.5	2.5	0.0	5.0	11.7
	11.0	14.9	16.7	5.3	0.0	14.3	
	6.7	2.0	2.0	0.3	0.0	0.6	
Wobble	3	0	0	0	2	0	5
	60.0	0.0	0.0	0.0	40.0	0.0	1.5
	1.4	0.0	0.0	0.0	18.2	0.0	
	0.9	0.0	0.0	0.0	0.6	0.0	
Weave	0	1	0	0	0	1	2
	0.0	50.0	0.0	0.0	0.0	50.0	0.6
	0.0	2.1	0.0	0.0	0.0	7.1	
	0.0	0.3	0.0	0.0	0.0	0.3	
Lost Wheelie	6	0	1	1	1	0	9
	66.7	0.0	11.1	11.1	11.0	0.0	2.6
	2.9	0.0	2.4	5.3	9.1	0.0	
	1.7	0.0	0.3	0.3	0.3	0.0	
Slide Out	120	29	24	12	5	6	196
	61.2	14.8	12.2	6.1	2.6	3.1	57.1
	57.1	61.7	57.1	63.2	45.5	42.9	
	35.0	8.5	7.0	3.5	1.5	1.7	
High Side	11	1	3	0	3	1	19
	57.9	5.3	15.8	0.0	15.8	5.3	5.5
	5.2	2.1	7.1	0.0	27.3	7.1	
	3.2	0.3	0.9	0.0	0.9	0.3	
Wide On Turn	46	9	7	5	0	4	71
	64.8	12.7	9.9	7.0	0.0	5.6	20.7
	21.9	19.1	16.7	26.3	0.0	28.6	
	13.4	2.6	2.0	1.5	0.0	1.2	
End Over	1	0	0	0	0	0	1
	100.0	0.0	0.0	0.0	0.0	0.0	0.3
	0.5	0.0	0.0	0.0	0.0	0.0	
	0.3	0.0	0.0	0.0	0.0	0.0	
Column Total	210	47	42	19	11	14	343
	61.2	13.7	12.2	5.5	3.2	4.1	100.0

developed for collision avoidance braking, and gave the impression of having no strategy or plan for traffic hazards. In great part, these riders gave the impression that they had made no mental preparation for traffic conflicts and were unprepared to deal with the precrash conditions as they developed.

Also, those riders involved in running wide on a turn loss of control gave the same impressions of having no plan or strategy for traffic hazards. In those cases where the rider entered a curve at excess speed, the ability to brake effectively was always absent. Also it appeared that most of these riders would lean adversely (they would straighten up rather than lean into the turn) and thereby reduce ground clearance and cornering ability, and many of the collision contact conditions confirmed this impression.

These data for the loss-of-control accidents show no real benefit of experience and any isolated advantages for the trained motorcycle rider. This information should not be applied to deny that there is a significant benefit of training because these data compare those riders involved in loss-of-control accidents. Training in collision avoidance braking, cornering, and traffic strategy is sure to reduce accident involvement.

7.19 Motorcycle Passenger Sex

Passengers were involved in 17.1% of the 900 on-scene, in-depth accident cases and 14.8% of the 3600 cases examined from the police traffic accident reports. Two of the on-scene, in-depth accident cases involved TWO passengers as well as the rider on the accident-involved motorcycle. Table 7.19.1 shows these data.

TABLE 7.19.1. PASSENGER INVOLVEMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
	0.	744	82.7	82.9
	1.	152	16.9	16.9
	2.	2	0.2	0.2
Unknown	8.	2	0.2	Missing
	TOTAL	900	100.0	100.0

Was Motorcycle Carrying Passenger? (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Yes	1.	529	14.7	14.8
No	2.	3044	84.6	85.2
Unknown-Not Reported	8.	27	0.7	Missing
	TOTAL	3600	100.0	100.0

Table 7.19.2 shows that 48.7% of the passengers identified in the 900 on-scene, in-depth cases were female, as were 47.9% of the passengers in the 3600 accident reports.

7.20 Motorcycle Passenger Height and Weight

Table 7.20.1 (Appendix C.3) shows the heights of the passengers from the 900 on-scene, in-depth accident cases.

TABLE 7.19.2. PASSENGER SEX (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Male	1.	78	8.7	51.3
Female	2.	74	8.2	48.7
N.A., No Passenger	9.	748	83.1	Missing
	TOTAL	900	100.0	100.0

Passenger Sex (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Female	F.	252	7.0	47.9
Male	M.	274	7.6	52.1
Unknown	8.	30	0.8	Missing
N.A., No Passenger	9.	3044	84.6	Missing
	TOTAL	3600	100.0	100.0

Table 7.20.2 (Appendix C.3) shows the weights of the passengers from the 900 on-scene, in-depth accident cases.

7.21 Motorcycle Passenger Occupation

Table 7.21.1 shows the occupation of the passenger from the 900 accident cases. The most frequent occupation stated was student, 38.2%.

7.22 Motorcycle Passenger Experience

Table 7.22.1 (Appendix C.3) shows the prior experience of the passenger on the motorcycles of the 900 on-scene, in-depth accident cases. Usually, the passenger is not experienced, with approximately two-thirds of the accident-involved passengers riding as passenger only occasionally, or never before. Also, Table 7.22.1 shows that the motorcycle rider usually has little experience riding with a passenger.

The carrying of a passenger can interfere with the driving task in many ways. The capabilities for braking and the swerving for collison avoidance are not significantly degraded by passenger carrying. However loss of control is much more likely during a brake skid or puncture flat. Also, a factor frequently encountered with passenger involvement was the distraction of the rider from the driving task, reducing attentiveness to traffic. The data of Table 7.22.1 show such a passenger interference in 27.2% of the passenger-involved accidents.

TABLE 7.21.1. PASSENGER OCCUPATION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Professional	1.	8	0.9	5.9
Sales Worker	3.	3	0.3	2.2
Clerical	4.	13	1.4	9.6
Craftsman	5.	9	1.0	6.6
Transport Operator	7.	1	0.1	0.7
Laborers	8.	20	2.2	14.7
Service Workers	11.	8	0.9	5.9
Housewife	13.	4	0.4	2.9
Student	14.	52	5.8	38.2
Military	15.	1	0.1	0.7
Unemployed	17.	17	1.9	12.5
Unknown	98.	16	1.8	Missing
N.A. No. Passenger	99.	748	83.1	Missing
	TOTAL	900	100.0	100.0

7.23 Motorcycle Passenger Alcohol and Drug Involvement

Table 7.23.1 (Appendix C.3) shows the passenger alcohol involvement for the 900 on-scene, in-depth cases. Of the 154 passengers, 16 (or 10.4%) had been drinking, but the exact involvement was difficult to determine.

Table 7.23.2 (Appendix C.3) shows the data collected for passenger drug involvement shows 3 cases of the passenger use of prescription or non-prescription drugs. These cases were independent of alcohol involvement.

The total involvement was 12.3% of the accident involved passengers.

7.24 Other Vehicle Driver Age

Table 7.24.1 shows the age of the driver of the other vehicle involved in collision with the motorcycle in the 900 on-scene, in-depth accident cases. The median age shown in this distribution is 34.4 years.

Table 7.24.2 shows the age of the driver of the other vehicle involved in collision with the motorcycle in the 3600 cases examined from police traffic accident reports. The median age shown in this distribution is 33.0 years.

7.25 Other Vehicle Driver Sex, Marital Status, Children

Table 7.25.1 shows the sex of the driver of the other vehicle involved in collision with the motorcycle. The distribution for the 900 on-scene, in-depth cases shows that 33.0% were female; the distribution for the 3600 traffic accident report cases shows that 34.5% were female.

TABLE 7.24.1. OTHER VEHICLE DRIVER AGE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Age, years	15.	1	0.1	0.2	0.2
	17.	4	0.4	0.6	0.8
	18.	10	1.1	1.6	2.4
	19.	17	1.9	2.8	5.2
	20.	19	2.1	3.1	8.3
	21.	28	3.1	4.5	12.8
	22.	25	2.8	4.1	16.9
	23.	23	2.6	3.7	20.6
	24.	20	2.2	3.2	23.8
	25.	27	3.0	4.4	28.2
	26.	19	2.1	3.1	31.3
	27.	18	2.0	2.9	34.2
	28.	17	1.9	2.8	37.0
	29.	18	2.0	2.9	39.9
	30.	9	1.0	1.5	41.3
	31.	13	1.4	2.1	43.4
	32.	17	1.9	2.8	46.2
	33.	10	1.1	1.6	47.8
	34.	9	1.0	1.5	49.3
	35.	12	1.3	1.9	51.2
	36.	10	1.1	1.6	52.8
	37.	11	1.2	1.8	54.6
	38.	11	1.2	1.8	56.4
	39.	11	1.2	1.8	58.2
	40.	10	1.1	1.6	59.8
	41.	6	0.7	1.0	60.8
	42.	10	1.1	1.6	62.4
	43.	4	0.4	0.6	63.0
	44.	14	1.6	2.3	65.3
	45.	10	1.1	1.6	66.9
	46.	12	1.3	1.9	68.9
	47.	6	0.7	1.0	69.9
	48.	12	1.3	1.9	71.8
	49.	9	1.0	1.5	73.3
	50.	7	0.8	1.1	74.4
	51.	6	0.7	1.0	75.4
	52.	7	0.8	1.1	76.5
	53.	12	1.3	1.9	78.4
	54.	8	0.9	1.3	79.7
	55.	4	0.4	0.6	80.4
	56.	7	0.8	1.1	81.5
	57.	6	0.7	1.0	82.5
	58.	7	0.8	1.1	83.6
	59.	5	0.7	1.0	84.6
	60.	7	0.8	1.1	85.7
	61.	8	0.9	1.3	87.0
	62.	6	0.7	1.0	88.0
	63.	6	0.7	1.0	89.0
	64.	7	0.8	1.1	90.1
	65.	12	1.3	1.9	92.1
	66.	6	0.7	1.0	93.0
	67.	3	0.3	0.5	93.5
	68.	5	0.6	0.8	94.3
	69.	5	0.6	0.8	95.1
	70.	2	0.2	0.3	95.5
	71.	1	0.1	0.2	95.6
	72.	1	0.1	0.2	95.8
	73.	1	0.1	0.2	95.9
	74.	3	0.3	0.5	96.4
	75.	4	0.4	0.6	97.1
	76.	3	0.3	0.5	97.6
	77.	2	0.2	0.3	97.9
	78.	4	0.4	0.6	98.5
	82.	2	0.2	0.3	98.9
	83.	1	0.1	0.2	99.0
	85.	2	0.2	0.3	99.4
	86.	3	0.3	0.5	99.8
	91.	1	0.1	0.2	100.0
Unknown	98.	73	8.1	Missing	100.0
Not Applicable	99.	210	23.3	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.24.2. OTHER VEHICLE DRIVER AGE (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Age, years	3.	1	0.0	0.0	0.0
	6.	5	0.1	0.2	0.2
	7.	1	0.0	0.0	0.3
	8.	1	0.0	0.0	0.3
	9.	2	0.1	0.1	0.4
	10.	5	0.1	0.2	0.6
	11.	4	0.1	0.2	0.8
	12.	4	0.1	0.2	0.9
	13.	5	0.1	0.2	1.1
	14.	3	0.1	0.1	1.3
	15.	1	0.0	0.0	1.3
	16.	9	0.2	0.4	1.7
	17.	45	1.2	1.8	3.5
	18.	66	1.8	2.7	6.1
	19.	80	2.2	3.2	9.4
	20.	76	2.1	3.1	12.4
	21.	89	2.5	3.6	16.0
	22.	80	2.2	3.2	19.2
	23.	84	2.3	3.4	22.6
	24.	79	2.2	3.2	25.8
	25.	87	2.4	3.5	29.3
	26.	65	1.8	2.6	31.9
	27.	63	1.7	2.5	34.5
	28.	85	2.4	3.4	37.9
	29.	68	1.9	2.7	40.7
	30.	67	1.9	2.7	43.4
	31.	66	1.8	2.7	46.0
	32.	58	1.6	2.3	48.4
	33.	43	1.2	1.7	50.1
	34.	59	1.6	2.4	52.5
	35.	45	1.2	1.8	54.3
	36.	42	1.2	1.7	56.0
	37.	36	1.0	1.5	57.4
	38.	36	1.0	1.5	58.9
	39.	42	1.2	1.7	60.6
	40.	37	1.0	1.5	62.1
	41.	37	1.0	1.5	63.6
	42.	28	0.8	1.1	64.7
	43.	45	1.2	1.8	66.5
	44.	28	0.8	1.1	67.6
	45.	39	1.1	1.6	69.2
	46.	24	0.7	1.0	70.2
	47.	36	1.0	1.5	71.6
	48.	46	1.3	1.9	73.5
	49.	27	0.7	1.1	74.6
	50.	38	1.1	1.5	76.1
	51.	46	1.3	1.9	78.0
	52.	36	1.0	1.5	79.4
	53.	37	1.0	1.5	80.9
	54.	36	1.0	1.5	82.9
	55.	23	0.6	0.9	83.3
	56.	28	0.8	1.1	84.4
	57.	40	1.1	1.6	86.0
	58.	25	0.7	1.0	87.1
	59.	31	0.9	1.3	88.3
	60.	22	0.6	0.9	89.2
	61.	16	0.4	0.6	89.8
	62.	17	0.5	0.7	90.5
	63.	20	0.6	0.8	91.3
	64.	26	0.7	1.0	92.4
	65.	16	0.4	0.6	93.0
	66.	17	0.5	0.7	93.7
	67.	22	0.6	0.9	94.6
	68.	15	0.4	0.6	95.2
	69.	16	0.4	0.6	95.8
	70.	5	0.1	0.2	96.0
	71.	7	0.2	0.3	96.3
	72.	10	0.3	0.4	96.7
	73.	16	0.4	0.6	97.4
	74.	11	0.3	0.4	97.8
	75.	14	0.4	0.6	98.4
	76.	5	0.1	0.2	98.6
	77.	11	0.3	0.4	99.0
	80.	2	0.1	0.1	99.1
	81.	7	0.2	0.3	99.4
	82.	1	0.0	0.0	99.4
	83.	3	0.1	0.1	99.6
	84.	2	0.1	0.1	99.6
	85.	3	0.1	0.1	99.8
	86.	1	0.0	0.0	99.8
	87.	1	0.0	0.0	99.8
	89.	1	0.0	0.0	99.9
	90.	1	0.0	0.0	99.9
	92.	1	0.0	0.0	100.0
	100.	1	0.0	0.0	100.0
Unknown & Not Applicable (Single Vehicle Acc)	99.	1121	31.1	Missing	100.0
	TOTAL	3600	100.0	100.0	

TABLE 7.25.1. OTHER VEHICLE DRIVER SEX (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Male	1.	444	49.3	67.0
Female	2.	219	24.3	33.0
Unknown	8.	29	3.2	Missing
N.A.-No Other Vehicle	9.	208	23.1	Missing
	TOTAL	900	100.0	100.0

Other Vehicle Driver Sex (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Female	F	891	24.7	34.5
Male	M	1691	47.0	65.5
Unknown-Not Reported	8	217	6.0	Missing
N.A. Single Veh Acc	9	801	22.2	Missing
	TOTAL	3600	100.0	100.0

Table 7.25.2 shows the marital status of the driver of the other vehicle involved in collision with the motorcycle in the 900 accident cases.

TABLE 7.25.2. OTHER VEHICLE DRIVER MARITAL STATUS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Single	1.	217	24.1	41.2
Married	2.	257	28.6	48.8
Separated	3.	11	1.2	2.1
Divorced	4.	31	3.4	5.9
Widowed	5.	7	0.8	1.3
Cohabitating	6.	4	0.4	0.8
Unknown	8.	164	18.2	Missing
N.A.-No Other Vehicle	9.	209	23.2	Missing
	TOTAL	900	100.0	100.0

Table 7.25.3 shows the number of children for the driver of the other vehicle involved in collision with the motorcycle in the 900 accident cases.

TABLE 7.25.3. OTHER VEHICLE DRIVER CHILDREN (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	230	25.6	47.5	47.5
	1.	75	8.3	15.5	63.0
	2.	85	9.4	17.6	80.6
	3.	54	6.0	11.2	91.7
	4.	25	2.8	5.2	96.9
	5.	8	0.9	1.7	98.6
	6.	4	0.4	0.8	99.4
Seven Or More	7.	3	0.3	0.6	100.0
Unknown	8.	207	23.0	Missing	100.0
N.A.-No Other Vehicle	9.	209	23.2	Missing	100.0
	TOTAL	900	100.0	100.0	

7.26 <u>Other Vehicle Driver Education and Occupation</u>

Table 7.26.1 shows the educational background for the drivers of the other vehicle involved in collision with the motorcycle in the 900 on-scene, in-depth accident cases.

TABLE 7.26.1. OTHER VEHICLE DRIVER EDUCATION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Graduate School	1.	47	5.2	9.6
College/Univ. Graduate	2.	58	6.4	11.9
Partial College	3.	134	14.9	27.5
High School	4.	138	15.3	28.3
Partial High School	5.	77	8.6	15.8
Jr. High School	6.	16	1.8	3.3
Less Than 7 Years	7.	18	2.0	3.7
Unknown	8.	203	22.6	Missing
Not Applicable	9.	209	23.2	Missing
	TOTAL	900	100.0	100.0

Table 7.26.2 shows the occupation of the driver of the other vehicle in the 900 on-scene, in-depth cases; Table 7.26.3 shows the occupation of the driver of the other vehicle in the 3600 traffic accident report cases. The distributions are comparable for those occupations noted with high frequency.

TABLE 7.26.2 OTHER VEHICLE DRIVER OCCUPATION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Professional	1.	78	8.7	13.1
Mgr./Administrator	2.	37	4.1	6.2
Sales Worker	3.	23	2.6	3.9
Clerical	4.	52	5.8	8.7
Craftsman	5.	54	6.0	9.1
Operatives, Non-Trans.	6.	4	0.4	0.7
Transport Operator	7.	27	3.0	4.5
Laborers	8.	73	8.1	12.2
Service Workers	11.	31	3.4	5.2
Housewife	13.	55	6.1	9.2
Student	14.	70	7.8	11.7
Military	15.	2	0.2	0.3
Retired	16.	35	3.9	5.9
Unemployed	17.	55	6.1	9.2
Unknown	98.	95	10.6	Missing
N.A.-No OV	99.	209	23.2	Missing
	TOTAL	900	100.0	100.0

Table 7.26.4 (Appendix C.3) shows the Hollingshead Index of social positon for the other vehicle driver in the 900 accident cases.

7.27 Other Vehicle Driver License Qualification

Table 7.27.1 (Appendix C.3) shows the license qualification of the driver of the other vehicle involved in collision with the motorcycle in the 900 accident cases. Unlicensed drivers comprised 6.1% of this accident-involved group.

Table 7.27.2 (Appendix C.3) shows the state of issue of that license qualification for the driver of the other vehicle. Out-of-state drivers were 3.6% of this group.

7.28 Other Vehicle Driver Experience

Table 7.28.1 shows the total driving experience of the driver of the other vehicle involved in collision with the motorcycle in the 900 on-scene, in-depth accident cases. Only 9.4% claimed less than 2 years experience, and the median experience was more than 8 years.

TABLE 7.26.3. OTHER VEHICLE DRIVER OCCUPATION (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Professional	1.	182	5.1	11.2
Administrator	2.	132	3.7	8.1
Sales Worker	3.	70	1.9	4.3
Clerical	4.	152	4.2	9.3
Craftsman	5.	134	3.7	8.2
Operatives	6.	41	1.1	2.5
Trans-Equip. Operative	7.	53	1.5	3.3
Laborers	8.	212	5.9	13.0
Farm Laborers	10.	1	0.0	0.1
Service Worker	11.	144	4.0	8.8
Housewife	13.	142	3.9	8.7
Student	14.	190	5.3	11.7
Military	15.	4	0.1	0.2
Retired	16.	63	1.7	3.9
Unemployed	17.	108	3.0	6.6
Unknown-Not Reported	98.	1171	32.5	Missing
N.A.-Single Veh. Acc.	99.	801	22.2	Missing
	TOTAL	3600	100.0	100.0

Table 7.28.2 shows the other vehicle driver experience with the accident-involved vehicle. 10.3% had less than 2 weeks experience with that vehicle but the median experience was 17.7 months.

Table 7.28.3 shows the accident history of the driver of the other vehicle. During the previous 2 years, 17.4% of those drivers had at least one reportable traffic accident.

An additional special survey was made for 68 of the drivers of the other vehicles involved in collision with the motorcycles in the 900 on-scene, in-depth accident cases. The objective was to recontact those drivers previously interviewed and determine their familiarity with motorcycles. Of course, the riders of the other motorcycles involved in collision with the motorcycles were not included. The results were as follows:

	Yes	No	Unknown
Does O/V driver have motorcycle experience?	2	62	4
Is a motorcycle owned by anyone in immediate family?	1	61	6
Is anyone in immediate family a regular motorcycle rider or passenger?	3	59	4

TABLE 7.28.1. OTHER VEHICLE DRIVER TOTAL DRIVING EXPERIENCE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Experience, months	0.	7	0.8	1.4	1.4
	1.	3	0.3	0.6	2.0
	3.	1	0.1	0.2	2.2
	4.	3	0.3	0.6	2.7
	5.	1	0.1	0.2	2.9
	6.	3	0.3	0.6	3.5
	7.	2	0.2	0.4	3.9
	8.	1	0.1	0.2	4.1
	9.	3	0.3	0.6	4.7
	10.	1	0.1	0.2	4.9
	12.	11	1.2	2.2	7.0
	13.	1	0.1	0.2	7.2
	18.	7	0.8	1.4	8.6
	20.	1	0.1	0.2	8.8
	21.	1	0.1	0.2	9.0
	23.	2	0.2	0.4	9.4
	24.	19	2.1	3.7	13.1
	25.	2	0.2	0.4	13.5
	29.	3	0.3	0.6	14.1
	30.	4	0.4	0.8	14.9
	33.	1	0.1	0.2	15.1
	36.	18	2.0	3.5	18.6
	42.	2	0.2	0.4	19.0
	47.	1	0.1	0.2	19.2
	48.	15	1.7	2.9	22.1
	50.	2	0.2	0.4	22.5
	51.	1	0.1	0.2	22.7
	54.	2	0.2	0.4	23.1
	59.	1	0.1	0.2	23.3
	60.	15	1.7	2.9	26.2
	66.	1	0.1	0.2	26.4
	72.	16	1.8	3.1	29.5
	84.	24	2.7	4.7	34.2
	90.	4	0.4	0.8	35.0
	96.	9	1.0	1.8	36.8
	97.	323	35.9	63.2	100.0
Unknown	98.	181	20.1	Missing	100.0
N.A. No OV	99.	208	23.1	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.28.2. OTHER VEHICLE DRIVER EXPERIENCE WITH ACCIDENT-INVOLVED VEHICLE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Experience, months	0.	52	5.8	10.3	10.3
	1.	33	3.7	6.5	16.8
	2.	17	1.9	3.4	20.2
	3.	13	1.4	2.6	22.7
	4.	18	2.0	3.6	26.3
	5.	4	0.4	0.8	27.1
	6.	16	1.8	3.2	30.2
	7.	10	1.1	2.0	32.2
	8.	8	0.9	1.6	33.8
	9.	13	1.4	2.6	36.4
	10.	4	0.4	0.8	37.2
	11.	2	0.2	0.4	37.5
	12.	35	3.9	6.9	44.5
	13.	2	0.2	0.4	44.9
	14.	2	0.2	0.4	45.3
	15.	3	0.3	0.6	45.8
	16.	3	0.3	0.6	46.4
	17.	1	0.1	0.2	46.6
	18.	23	2.6	4.5	51.2
	19.	3	0.3	0.6	51.8
	20.	2	0.2	0.4	52.2
	21.	2	0.2	0.4	52.6
	22.	1	0.1	0.2	52.8
	23.	2	0.2	0.4	53.2
	24.	44	4.9	8.7	61.9
	26.	3	0.3	0.6	62.5
	27.	2	0.2	0.4	62.8
	28.	3	0.3	0.6	63.4
	29.	1	0.1	0.2	63.6
	30.	12	1.3	2.4	66.0
	34.	1	0.1	0.2	66.2
	36.	52	5.8	10.3	76.5
	37.	1	0.1	0.2	76.7
	38.	3	0.3	0.6	77.3
	40.	2	0.2	0.4	77.7
	41.	1	0.1	0.2	77.9
	42.	4	0.4	0.8	78.7
	45.	2	0.2	0.4	79.1
	47.	1	0.1	0.2	79.2
	48.	18	2.0	3.6	82.3
	49.	1	0.1	0.2	83.0
	51.	1	0.1	0.2	83.2
	54.	1	0.1	0.2	83.4
	56.	3	0.3	0.6	84.0
	60.	15	1.7	3.0	87.0
	63.	1	0.1	0.2	87.2
	64.	2	0.2	0.4	87.5
	67.	1	0.1	0.2	87.7
	69.	1	0.1	0.2	87.9
	70.	1	0.1	0.2	88.1
	72.	13	1.4	2.6	90.7
	73.	1	0.1	0.2	90.9
	75.	1	0.1	0.2	91.1
	78.	2	0.2	0.4	91.5
	82.	1	0.1	0.2	91.7
	84.	9	1.0	1.8	93.5
	87.	1	0.1	0.2	93.7
	90.	1	0.1	0.2	93.9
	96.	10	1.1	2.0	95.8
	97.	21	2.3	4.2	100.0
Unknown	98.	185	20.6	Missing	100.0
N.A.-No Other Vehicle	99.	209	23.2	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.28.3 NUMBER OF OTHER VEHICLE DRIVER ACCIDENTS WITHIN LAST 2 YEARS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Accidents	0.	462	51.3	82.6
	1.	77	8.6	13.8
	2.	12	1.3	2.1
	3.	6	0.7	1.1
	4.	2	0.2	0.4
Unknown	8.	132	14.7	Missing
N.A.	9.	209	23.2	Missing
	TOTAL	900	100.0	100.0

These results generally show that the motorcycle is an unfamiliar object in traffic. This fact may be critical in the detection of traffic hazards; the motorcycle may be an unfamiliar as well as inconspicuous object in traffic.

7.29 Other Vehicle Driver Alcohol and Drug Involvement

Table 7.29.1 shows the alcohol and drug involvement for the drivers of the other vehicle involved in collision with the motorcycle. The data for the 900 on-scene, in-depth accident cases shows that 44 other vehicle drivers had some involvement, which is 6.4% of the 691 cases with another vehicle driver. The data for the 3600 traffic accident report cases shows 3.7% had some involvement.

Table 7.29.2 shows the blood alcohol level for those drivers of the other vehicles involved in the 900 accident cases.

Table 7.29.3 shows the drug involvement for the other vehicle driver.

TABLE 7.29.1. OTHER VEHICLE DRIVER ALCOHOL-DRUG IMPAIRMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
HBD, Not Under Infl.	1.	12	1.3	27.3	27.3
HBD, Under Influence	2.	23	2.6	52.3	79.5
HBD, Impairment Unk.	3.	7	0.8	15.9	95.5
Combination	5.	1	0.1	2.3	97.7
Other	6.	1	0.1	2.3	100.0
Unknown	8.	78	8.7	Missing	100.0
N.A., No Impairment or Single Veh. Acc.	9.	778	86.4	Missing	100.0
	TOTAL	900	100.0	100.0	

Other Vehicle Driver Alcohol-Drug Impairment (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
HNBD	1.	2387	66.3	96.2	96.2
HBD-Influence Unk.	2.	88	2.4	3.5	99.8
Drug Influence	3.	6	0.2	0.2	100.0
Unknown	8.	315	8.7	Missing	100.0
N.A., Single Veh. Acc.	9.	804	22.3	Missing	100.0
	TOTAL	3600	100.0	100.0	

TABLE 7.29.2. OTHER VEHICLE DRIVER BLOOD ALCOHOL LEVEL (PERCENT) (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Blood Alcohol, (%)	.00	562	64.2	96.6	96.6
	.07	1	0.1	0.2	96.7
	.10	2	0.2	0.3	97.1
	.11	1	0.1	0.2	97.3
	.14	1	0.1	0.2	97.4
	.16	1	0.1	0.2	97.6
	.17	3	0.3	0.5	98.1
	.18	1	0.1	0.2	98.3
	.19	3	0.3	0.5	98.8
	.22	2	0.2	0.3	99.1
	.23	1	0.1	0.2	99.3
	.25	1	0.1	0.2	99.5
	.27	1	0.1	0.2	99.7
	.29	1	0.1	0.2	99.8
	.36	1	0.1	0.2	100.0
Unknown	.98	100	11.1	Missing	100.0
N.A.	.99	218	24.2	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 7.29.3. OTHER VEHICLE DRIVER USE OF DRUGS OTHER THAN ALCOHOL (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Prescription Status					
None	0.	561	62.3	99.1	99.1
Prescription	1.	4	0.4	0.7	99.8
Non-Prescription	2.	1	0.1	0.2	100.0
Unknown	8.	118	13.1	Missing	100.0
N.A.	9.	216	24.0	Missing	100.0
	TOTAL	900	100.0	100.0	
Type of Drug					
None	0.	559	62.1	99.1	99.1
Marijuana	1.	2	0.2	0.4	99.5
Stimulant	2.	1	0.1	0.2	99.6
Depressant-Antihistamine	5.	1	0.1	0.2	99.8
Multiple	7.	1	0.1	0.2	100.0
Unknown	8.	127	14.1	Missing	100.0
N.A.	9.	209	23.2	Missing	100.0
	TOTAL	900	100.0	100.0	

8.0 HUMAN FACTORS — INJURIES

This section deals with the injuries suffered by the motorcycle riders and passengers in the accidents which were investigated and analyzed. The most accurate data were available from the 900 on-scene, in-depth accident cases, where the injuries were observed directly, obtained from record or interview of the treating physician, or recorded from autopsy. These injuries are analyzed for body region, system, severity and mechanism so that cause and severity can be studied for appropriate countermeasures.

8.1 Injuries - General Characteristics

Table 8.1.1 shows the status of injuries for the 900 motorcycle riders and 152 motorcycle passengers involved in the 900 on-scene, in-depth cases, and distinguished for the multiple and single vehicle collisions. A special feature of these data is that the riders and passengers suffered some kind of injury in 98% of the multiple vehicle accidents and 96% of the single vehicle accidents. This very high involvement of injury may be due in great part to the character of the accidents as acquired, since accident notification was dependent primarily upon dispatch of a rescue ambulance.

TABLE 8.1.1. INJURY STATUS FOR THE MOTORCYCLE RIDERS IN THE 900 OSIDIs

	Multiple Vehicle Collisions			Single Vehicle Collisions		
	Rider	Passenger	Total	Rider	Passenger	Total
No Injury	12	4	16	9	2	11
Injury	619	102	721	203	38	241
Fatal	36	2	38	18	3	21
Total	667	108	775	230	43	273
(Note: Unknown status for 2 riders and 1 passenger)						

Also shown in Table 8.1.1 is that the incidence of fatal injury is 4.9% of the multiple vehicle accidents and 7.7% of the single vehicle accidents.

Table 8.1.2 shows the frequency of injury severity for the most severe injuries suffered by the 900 motorcycle riders and the 152 motor cycle passengers involved in the 900 on-scene, in-depth accident cases. The high injury rate typical of motorcycle accidents is shown in these data by the fact that 45.1% of the riders and passengers suffered something more than a minor injury, and 24.1% had an injury which was severe, serious, critical or fatal.

TABLE 8.1.2. FREQUENCY OF INJURY SEVERITY FOR MOST SEVERE INJURY, ALL REGIONS RIDERS AND PASSENGERS

Most Severe Injury	Count / Row Pct / Col Pct / Tot Pct	Rider	Passenger	Row Total
None		21 80.8 2.3 2.0	5 19.2 3.3 0.5	26 2.5
Minor		457 82.9 50.8 43.4	94 17.1 61.8 8.9	551 52.4
Moderate		197 89.1 21.9 18.7	24 10.9 15.8 2.3	221 21.0
Severe		105 86.1 11.7 10.0	17 13.9 11.2 1.6	122 11.6
Serious		51 92.7 5.7 4.8	4 7.3 2.6 0.4	55 5.2
Critical		37 84.1 4.1 3.5	7 15.9 4.6 0.7	44 4.2
Fatal		30 96.8 3.3 2.9	1 3.2 0.7 0.1	31 2.9
Unknown		2 100.0 0.2 0.2	0 0.0 0.0 0.0	2 0.2
	Column Total	900 85.6	152 14.4	1052 100.0

Table 8.1.3 shows the regions of these most severe injuries for the riders and passengers involved in the 900 on-scene, in-depth accident cases. Note that injuries to the extremities are 45.5% of these most severe injuries in each accident. However, these injuries to the extremities are surely frequent but never any threat to life. The next most frequent set of injuries in these data is to the head, neck and face, which comprise a total of 28.5% of the total of most severe injuries.

Note that the areas of the passenger body which benefit from some shielding by the rider body in frontal impact have lower incidence, e.g., extremities, pelvis and abdomen.

8.2 Rider and Passenger Positions on the Motorcycle at Crash Impact

Table 8.2.1 shows the rider position on the motorcycle at crash impact. The great majority, 91.1% of the motorcycle riders, were in the normal riding position at the time of crash impact. In reaction to the imminent collision some riders stood up on the foot pegs (2.6%), some riders made a head or shoulder check (2.1%), and some riders were in the process of "bailing out."

Table 8.2.2 shows a cross tabulation of this rider precrash action and the overall Severities Sum, $SS = \Sigma(AIS)^2$. These data show a significantly lower injury Severities Sum for those riders who were dismounting in advance of the collision. Two such cases should be described to explain this advantage shown. One case involved an extremely aware and athletic rider who intentionally vaulted over the hood of a car that suddenly blocked his path of travel, then tumbled and rolled to a stop with only minor abrasions and contusions. Another case involved the simple but effective action of a rider who lifted his right leg and began dismounting to the left, thereby avoiding the impact of an automobile front corner and bumper on the right leg.

Interpretation of these data allow speculation of great and skillful reactions which are beyond the great majority of motorcycle riders. The precrash events happen in very short time and rider strategy should focus first on preventing accident involvement, then improving collision avoidance action. Dismounting in the precrash time is a last resort, and needs to be reserved for those appropriate times. "Bailing out" into the path of an eighteen wheeler when you have a puncture flat may not be the correct choice — but there may not be alternatives.

The most important impressions from these data are that close proximity to the motorcycle at the point of impact is injurious indeed, and the majority of the riders do nothing and crash in the normal seated position.

Table 8.2.3 shows that the great majority of the accident involved passengers (94.6%) were in the normal riding position at the time of the crash impact.

TABLE 8.1.3. REGION OF MOST SEVERE INJURY
RIDERS AND PASSENGERS

Region — Count / Row Pct / Col Pct / Tot Pct	Rider	Passenger	Row Total
No Injury	21 80.8 2.3 2.0	5 19.2 3.3 0.5	26 2.5
Extremities	419 87.5 46.6 39.8	60 12.5 39.5 5.7	479 45.5
Pelvis	62 88.6 6.9 5.9	8 11.4 5.3 0.8	70 6.7
Abdomen	48 92.3 5.3 4.6	4 7.7 2.6 0.4	52 4.9
Chest	97 79.5 10.8 9.2	25 20.5 16.4 2.4	122 11.6
Face	53 84.1 5.9 5.0	10 15.0 6.6 1.0	63 6.0
Neck	30 81.1 3.3 2.9	7 18.9 4.6 0.7	37 3.5
Head	168 84.0 18.7 16.0	32 16.0 21.1 3.0	200 19.0
Unknown	1 100.0 0.1 0.1	0 0.0 0.0 0.0	1 0.1
Whole Body	1 50.0 0.1 0.1	1 50.0 0.7 0.1	2 0.2
Column Total	900 85.6	152 14.4	1052 100.0

TABLE 8.2.1. RIDER POSITION ON MOTORCYCLE AT CRASH IMPACT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Normal Seated	1.	813	90.3	91.1
Standing on Pegs	2.	23	2.6	2.6
Head Down	3.	5	0.6	0.6
Check Left	4.	5	0.6	0.6
Check Right	5.	8	0.9	0.9
Dismounting	6.	32	3.6	3.6
Other	7.	6	0.7	0.7
Unknown	8.	8	0.9	Missing
	TOTAL	900	100.0	100.0

8.3 Motorcycle, Rider and Passenger Motion After Collision Contact

Table 8.3.1 shows the motion of the motorcycle after collision contact for the 900 on-scene, in-depth accident cases. Table 8.3.2 shows the motion of the motorcycle rider after collision contact for the 900 accident cases.

Table 8.3.3 shows the time when the motorcycle and rider separated. The 2.7% of the motorcycle riders who separated from the motorcycle in the precrash time did so intentionally and were dismounting in reaction to the imminent collision. Note that 11.9% of the accidents did not involve separation and the motorcycle and rider were together at the point of rest. A great part of these riders were trapped under the motorcycle.

Table 8.3.4 shows the motion of the accident-involved passenger after collision contact.

Without exception those motorcycle riders and passengers trapped or dragged by the other vehicle had severe or serious injuries (AIS: 3 or 4).

8.4 On-Scene Medical Assistance and Injury Status, Motorcycle Rider and Passenger

Table 8.4.1 shows the medical assistance given to the accident-involved motorcycle rider at the accident scene. Table 8.4.2 describes the details of that on-scene medical treatment given to the motorcycle rider. Table 8.4.3 shows the injury status for the motorcycle rider. These data show that 56.4% of the accident-involved motorcycle riders had no injury, or required only limited treatment for minor injuries, but 36.3% had injuries requiring significant medical care. Most of the fatally injured riders were dead shortly after the accident, usually at the accident scene.

TABLE 8.2.2. RIDER PRECRASH POSITION ON MOTORCYCLE BY OVERALL SEVERITIES SUM (OSIDs)

Count Row Pct Col Pct Tot Pct	0 Through 5	6 Through 10	11 Through 25	26 Through 50	51 Through 100	More Than 100	Row Total
Normal Seated	391	180	142	45	26	29	813
	48.1	22.1	17.5	5.5	3.2	3.6	90.3
	88.3	91.4	92.2	95.7	86.7	100.0	
	43.4	20.0	15.8	5.0	2.9	3.2	
Standing on Pegs	11	6	4	1	1	0	23
	47.8	26.1	17.4	4.3	4.3	0.0	2.6
	2.5	3.0	2.6	2.1	3.3	0.0	
	1.2	0.7	0.4	0.1	0.1	0.0	
Head Down	1	2	0	0	2	0	5
	20.0	40.0	0.0	0.0	40.0	0.0	0.6
	0.2	1.0	0.0	0.0	6.7	0.0	
	0.1	0.2	0.0	0.0	0.2	0.0	
Check Left	2	1	2	0	0	0	5
	40.0	20.0	40.0	0.0	0.0	0.0	0.6
	0.5	0.5	1.3	0.0	0.0	0.0	
	0.2	0.1	0.2	0.0	0.0	0.0	
Check Right	3	3	2	0	0	0	8
	37.5	37.5	25.0	0.0	0.0	0.0	0.9
	0.7	1.5	1.3	0.0	0.0	0.0	
	0.3	0.3	0.2	0.0	0.0	0.0	
Dismounting	26	3	3	0	0	0	32
	81.3	9.4	9.4	0.0	0.0	0.0	3.6
	5.9	1.5	1.9	0.0	0.0	0.0	
	2.9	0.3	0.3	0.0	0.0	0.0	
Other	4	1	1	0	0	0	6
	66.7	16.7	16.7	0.0	0.0	0.0	0.7
	0.9	0.5	0.6	0.0	0.0	0.0	
	0.4	0.1	0.1	0.0	0.0	0.0	
Unknown	5	1	0	1	1	0	8
	62.5	12.5	0.0	12.5	12.5	0.0	0.9
	1.1	0.5	0.0	2.1	3.3	0.0	
	0.6	0.1	0.0	0.1	0.1	0.0	
Column Total	443	197	154	47	30	29	900
	49.2	21.9	17.1	5.2	3.3	3.2	100.0

TABLE 8.2.3. PASSENGER POSITION ON MOTORCYCLE AT CRASH IMPACT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Normal Seated	1.	139	15.4	94.6
Standing	2.	2	0.2	1.4
Head Down	3.	1	0.1	0.7
Check Right	5.	2	0.2	1.4
Dismounting	6.	3	0.3	2.0
Unknown	8.	4	0.4	Missing
N.A.	9.	749	83.2	Missing
	TOTAL	900	100.0	100.0

TABLE 8.3.1. MOTORCYCLE POST-CRASH MOTION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Remained at POI	0.	235	26.1	26.2
Deflected to Side	1.	263	29.2	29.3
Became Airborne	2.	7	0.8	0.8
Slid to Stop	3.	309	34.3	34.4
End-Overs	4.	13	1.4	1.4
Trapped by OV	5.	65	7.2	7.2
Other	6.	6	0.7	0.7
Unknown	8.	2	0.2	Missing
	TOTAL	900	100.0	100.0

TABLE 8.3.2. MOTORCYCLE RIDER POST-CRASH MOTION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Stopped Near POI	0.	82	9.1	9.3
Vaulted From MC	1.	240	26.7	27.1
Fell From MC	2.	233	25.9	26.4
Tumbled or Rolled	3.	115	12.8	13.0
Slid to Stop	4.	103	11.4	11.7
Trapped Under MC	5.	79	8.8	8.9
Trapped Under OV	6.	21	2.3	2.4
Struck and Dragged by OV	7.	11	1.2	1.2
Unknown	8.	6	0.7	Missing
NA	9.	10	1.1	Missing
	TOTAL	900	100.0	100.0

TABLE 8.3.3. MOTORCYCLE AND RIDER SEPARATION

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Pre-Crash	1.	24	2.7
Crash	2.	457	50.8
Post-Crash	3.	305	33.9
Unknown	8.	7	0.8
NA, No Separation	9.	107	11.9
	TOTAL	900	100.0

TABLE 8.3.4. PASSENGER POST-CRASH MOTION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Stopped Near POI	0.	22	2.4	14.3
Vaulted From MC	1.	33	3.7	21.4
Fell From MC	2.	48	5.3	31.2
Tumbled or Rolled	3.	22	2.4	14.3
Slid to Stop	4.	15	1.7	9.7
Trapped Under MC	5.	7	0.8	4.5
Trapped Under OV	6.	6	0.7	3.9
Struck and Dragged by OV	7.	1	0.1	0.6
Unknown	8.	1	0.1	Missing
NA	9.	745	82.8	Missing
	TOTAL	900	100.0	100.0

TABLE 8.4.1. MEDICAL ASSISTANCE TO MOTORCYCLE RIDER

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	118	13.1	13.1
Private Ambulance	1.	9	1.0	1.0
Public Ambulance	2.	736	81.8	82.2
M.D. On-Scene	3.	1	0.1	0.1
Coroner	4.	18	2.0	2.0
Private Party	5.	9	1.0	1.0
Police	6.	6	0.7	0.7
Other	7.	1	0.1	0.1
Unknown	8.	2	0.2	Missing
	TOTAL	900	100.0	100.0

TABLE 8.4.2. MOTORCYCLE RIDER ON-SCENE MEDICAL TREATMENT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Hemorrhage Control — Rider				
None	0.	521	57.9	61.4
Yes	1.	327	36.3	38.6
Unknown	8.	52	5.8	Missing
	TOTAL	900	100.0	100.0
Splinting of Limbs — Rider				
None	0.	576	64.0	68.1
Yes	1.	270	30.0	31.9
Unknown	8.	54	6.0	Missing
	TOTAL	900	100.0	100.0
Resuscitation — Rider				
None	0.	815	90.6	96.0
Yes	1.	34	3.8	4.0
Unknown	8.	51	5.7	Missing
	TOTAL	900	100.0	100.0
I.V. or Injections — Rider				
None	0.	741	82.3	88.4
Yes	1.	97	10.8	11.6
Unknown	8.	62	6.9	Missing
	TOTAL	900	100.0	100.0
Cardio Vascular RX — Rider				
None	0.	828	92.0	97.4
Yes	1.	22	2.4	2.6
Unknown	8.	50	5.6	Missing
	TOTAL	900	100.0	100.0
RX of Head Wounds — Rider				
None	0.	769	85.4	90.0
Yes	1.	85	9.4	10.0
Unknown	8.	46	5.1	Missing
	TOTAL	900	100.0	100.0

TABLE 8.4.3. MOTORCYCLE RIDER INJURY STATUS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
First Aid-Scene	1.	80	8.9	10.1
Treated, Released	2.	328	36.4	41.6
Hos. < 24 Hrs	3.	29	3.2	3.7
Hosp. Significant Rx	4.	219	24.3	27.8
Outpatient Care	5.	79	8.8	10.0
Dead on Scene	6.	31	3.4	3.9
Dead on Arrival	7.	10	1.1	1.3
Fatal Within 24 Hrs	8.	9	1.0	1.1
Other Fatal	9.	4	0.4	0.5
Unknown	98.	4	0.4	Missing
N A No Injury or No Treatment	99.	107	11.9	Missing
	TOTAL	900	100.0	100.0

Table 8.4.4 (Appendix C.4) shows the medical assistance given to the 152 passengers involved in the 900 on-scene, in-depth accident cases. Table 8.4.5 (Appendix C.4) describes the details of that on-scene medical treatment given to the passengers. Table 8.4.6 (Appendix C.4) shows the injury status for the motorcycle passengers. The passenger data show that 37.9% of the motorcycle passengers had injuries requiring significant medical care.

The high participation of public rather than private ambulance activity was due to the fact that the Los Angeles Fire Department provides the public ambulance response to the scenes of traffic accidents. The victims were transported to the emergency rooms of nearby hospitals under contract to the City of Los Angeles for emergency medical service.

8.5 Somatic (Body) Region Injuries

Table 8.5.1 shows the motorcycle rider injury severity for the 3600 traffic accident report cases. Table 8.5.2 shows the location of the rider somatic injuries defined by those 3600 traffic accident reports. (In these data, "somatic" is used to describe everything other than head and neck.)

Table 8.5.3 shows the motorcycle passenger injury severity for the 3600 traffic accident report cases. Table 8.5.4 shows the location of the passenger somatic injuries defined by those 3600 traffic accident reports.

In general, the extraction of injury data from the traffic accident reports was difficult and required truly excess effort in interpretation. Case-by-case comparison with the 900 on-scene in-depth cases showed a low fidelity of injury representation by the traffic accident reports. As an extreme, it would be expected that the fatal accident cases would be closely represented by the traffic

TABLE 8.5.1. MOTORCYCLE RIDER INJURY SEVERITY
(TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Major	A	479	13.3	13.6	13.6
Minor	B	2033	56.5	57.8	71.4
Complaint of Pain	C	583	16.2	16.6	88.0
Fatal	K	44	1.2	1.3	89.2
None	0	379	10.5	10.8	100.0
Unknown	8	82	2.3	Missing	100.0
	TOTAL	3600	100.0	100.0	

TABLE 8.5.2. MOTORCYCLE RIDER SOMATIC INJURY LOCATION
(TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Torso Injury				
None	0.	2140	59.4	68.2
Yes	1.	1000	27.8	31.8
Unknown-not reported	8.	460	12.8	Missing
	TOTAL	3600	100.0	100.0
Arm Injury				
None	0.	1936	53.8	61.8
Yes	1.	1199	33.3	38.2
Unknown-not reported	8.	465	12.9	Missing
	TOTAL	3600	100.0	100.0
Leg Injury				
None	0.	1221	33.9	38.9
Yes	1.	1918	53.3	61.1
Unknown-Not Reported	8.	461	12.8	Missing
	TOTAL	3600	100.0	100.0

TABLE 8.5.3. MOTORCYCLE PASSENGER INJURY SEVERITY
(TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Major	A	57	1.6	11.0
Minor	B	234	7.9	54.7
Complaint of Pain	C	114	3.2	22.0
Fatal	K	3	0.1	0.6
None	0	61	1.7	11.8
Unknown-Not Reported	8	37	1.0	Missing
N.A.-No Passenger	9	3044	84.6	Missing
	TOTAL	3600	100.0	100.0

TABLE 8.5.4. MOTORCYCLE PASSENGER SOMATIC INJURY LOCATION
(TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>MC Passenger Torso Injury</u>				
None	0.	327	9.1	70.3
Yes	1.	138	3.8	29.7
Unknown-Not Reported	8.	91	2.5	Missing
N.A.-No Passenger	9.	3044	84.6	Missing
	TOTAL	3600	100.0	100.0
<u>MC Passenger Arm Injury</u>				
None	0.	301	8.4	64.7
Yes	1.	164	4.6	35.3
Unknown-Not Reported	8.	91	2.5	Missing
N.A.-No Passenger	9.	3044	84.6	Missing
	TOTAL	3600	100.0	100.0
<u>MC Passenger Leg Injury</u>				
None	0.	206	5.7	44.3
Yes	1.	259	7.2	55.7
Unknown-Not Reported	8.	92	2.6	Missing
N.A.-No Passenger	9.	3043	84.5	Missing
	TOTAL	3600	100.0	100.0

accident reports. This was not the case here. The fatal accident cases in the 900 on-scene, in-depth investigations are contained completely within the 3600 traffic accident reports examined. For comparison, examine the following:

	900 OSIDs	3600 TARs
Motorcycle Rider Fatalities	54	44
Passenger Fatalities	5	3

A comparison of the two data sets confirms that the traffic accident reports do not report those deaths that occur some time (e.g. 48 hours) after the accident, as in the case of a later death due to burns or head injury.

Table 8.5.5 shows the body region of injuries to the motorcycle riders involved in the 900 on-scene, in-depth cases. These 900 riders suffered 3016 discrete injuries to the body (not including head and neck regions). The regions of highest frequency were the knee (14.3%) and the lower leg (14.1%). These injuries to the knee and lower leg were very common, and sometimes serious or severe, but never a threat to life. Those serious and severe injuries to the knee and lower leg generally showed long periods of recovery and/or disablement for the victim.

In order to compare the data of Table 8.5.5 with the previous data from the 3600 traffic accident reports, these injuries are combined as follows:

ARMS		LEGS		TORSO	
A	3.3%	K	14.3	B	4.4
E	5.6	L	14.1	C	6.9
R	5.8	Q	8.5	M	7.1
S	5.3	T	7.5	O	0.2
W	11.3			P	5.8
X	0.2			Y	0.2
	31.5%		44.4%		24.6%

Then comparing,

	900 OSIDs 3016 Injuries	3600 TARs Any Injury
ARMS	31.5%	38.2%
LEGS	44.4%	61.1%
TORSO	24.6%	31.8%

Thus, the traffic accident reports data seem to excessively represent somatic injury information.

TABLE 8.5.5. SOMATIC INJURY BODY REGION
(OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Upper Arm	A	98	3.2	3.3
Back	B	132	4.4	4.4
Chest	C	207	6.9	6.9
Elbow	E	168	5.6	5.6
Knee	K	432	14.3	14.3
Lower Leg	L	424	14.1	14.1
Abdomen	M	215	7.1	7.1
Whole Body	O	6	0.2	0.2
Pelvis/Hip	P	176	5.8	5.8
Ankle/Foot	Q	256	8.5	8.5
Forearm	R	174	5.8	5.8
Shoulders	S	161	5.3	5.3
Thigh	T	211	7.0	7.0
Unknown	U	4	0.1	0.1
Wrist/Hand	W	341	11.3	11.3
Upper Extremities	X	6	0.2	0.2
Trunk	Y	5	0.2	0.2
	TOTAL	3016	100.0	100.0

Chest injuries were frequent (6.9%) and had the greatest prospect for critical or fatal results. Typical life-threatening injuries to the chest were rib fractures associated with lacerated lungs and major blood vessels, and circulatory system parts which were lacerated and ruptured from impact inertial loading.

Table 8.5.6 shows the side of the rider somatic injury for the 900 on-scene, in-depth accident cases. The distribution of these injuries shows no dominance of right or left side injuries; the distribution shows <u>essentially symmetrical injuries</u>.

TABLE 8.5.6. SIDE OF RIDER SOMATIC INJURY
(OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Bilateral	B	390	12.9	13.0
Central	C	229	7.6	7.6
Left	L	1207	40.0	40.2
Right	R	1175	39.0	39.2
Unknown	U	15	0.5	Missing
	TOTAL	3016	100.0	100.0

Table 8.5.7 shows the type of lesion for the 3016 discrete somatic injuries. As expected for the exposed, and sometimes lightly protected somatic regions, abrasions predominate as 37.2% of all injuries. Of course in many of the minor accidents, abrasions were the only injury. It was rare that the abrasion injury had high severity since any substantial clothing will reduce abrasion injury. The outstanding case of high severity abrasion involved a motorcycle rider wearing only a Speedo bathing suit and falling on the abrasive asphalt paving at 32 mph.

Fractures and dislocations accounted for 16.0% of all injuries to the accident-involved motorcycle riders.

Table 8.5.8 shows the system or organ involved in the 3016 somatic injuries. It is clear that the exposed outer body surface of the motorcycle rider sustained the greatest part of these injuries; the abrasions, contusions and lacerations of the integument accounted for 64.7% of all the somatic injuries. Fractures, dislocations sprains, etc., of the skeletal structure (and joints) accounted for 22.7% of all the somatic injuries. Of course, those less frequent injuries to the arteries and heart were a far greater threat to life and were associated with much more severe accident impacts.

Table 8.5.9 shows the severity of the 3016 discrete somatic injuries. 75.1% of those injuries were minor, and most were integumentary abrasions. Only 12 of the injuries were fatal, although the data include 54 rider fatalities. The majority of those 54 fatalities were due to the combined effects of several injuries, many of which were critical injuries.

TABLE 8.5.7. RIDER SOMATIC INJURY, SYSTEM-ORGAN INVOLVED (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Abrasion	A	1123	37.2
Burn	B	11	0.4
Contusion	C	663	22.0
Dislocation	D	33	1.1
Fracture	F	449	14.9
Swelling	G	25	0.8
Hemorrhage	H	22	0.7
Laceration	L	352	11.7
Amputation	M	5	0.2
Crushing	N	5	0.2
Other	O	2	0.0
Pain	P	200	6.6
Rupture	R	17	0.6
Sprain	S	89	3.0
Unknown	U	4	0.1
Avulsion	V	16	0.5
	TOTAL	3016	100.0

TABLE 8.5.8. RIDER SOMATIC INJURY, TYPE OF LESION
(OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Arteries	A	17	0.6	0.6
Digestive	D	6	0.2	0.2
Urogenital	G	119	3.9	4.1
Heart	H	17	0.6	0.6
Integumentary	I	1872	62.1	64.7
Joints	J	195	6.5	6.8
Kidney	K	7	0.2	0.2
Liver	L	19	0.6	0.6
Muscle	M	78	2.6	2.7
Nervous System	N	1	0.0	0.0
Pulmonary/Lung	P	37	1.2	1.3
Spleen	Q	17	0.6	0.6
Respiratory	R	1	0.0	0.0
Skeletal	S	420	13.9	14.5
Unknown	U	120	3.9	Missing
Vertebrae	V	40	1.3	1.4
All Systems in Region	W	50	1.7	1.8
	TOTAL	3016	100.0	100.0

TABLE 8.5.9. RIDER SOMATIC INJURY SEVERITY
(OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Minor	1	2263	75.0
Moderate	2	384	12.7
Severe	3	216	7.2
Serious	4	99	3.3
Critical	5	40	1.3
Fatal	6	12	0.4
Unknown	8	2	0.0
	TOTAL	3016	100.0

Table 8.5.10 shows the rider somatic injuries collected according to manufacturer of the accident-involved motorcycle.

The last column of this table compares the frequency of that motorcycle make in the accident population. From this comparison it is seen that there is no significant over- or under-representation of injuries; each make accounts for its approximate fair share of injuries.

Table 8.5.11 shows the rider somatic injuries collected according to the engine displacement of the accident-involved motorcycles. Detailed examination of these data and comparison with the accident-involved population provides the following information:

(i) Motorcycles of 250cc or less are 22.6% of the accident population and account for 20.9% of these rider somatic injuries.

(ii) Motorcycles of 500cc or less are 58.9% of the accident population and account for 57.4% of these rider somatic injuries.

(iii) Motorcycles of 750cc or greater are 33.0% of the accident population and account for 35.1% of these rider somatic injuries.

(iv) 350cc motorcycles are 14.1% of the accident population and account for 13.9% of these rider somatic injuries.

(v) 750cc motorcycles are 17.5% of the accident population and account for 19.2% of these rider somatic injuries.

(vi) 1200cc motorcycles are 7.3% of the accident population and account for 8.3% of these rider somatic injuries.

TABLE 8.5.10. RIDER SOMATIC INJURIES AND MOTORCYCLE MANUFACTURER (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Motorcycle Population (%)
BMW	3.	47	1.6	1.6	1.6
BSA	4.	28	0.9	0.9	0.9
Bultaco	6.	2	0.1	0.1	0.1
CZ	8.	6	0.2	0.2	0.2
Cat-HPE	9.	5	0.2	0.2	0.1
Ducati	14.	8	0.3	0.3	0.2
Harley-Davidson	20.	343	11.4	11.4	10.5
Honda	23.	1636	54.2	54.2	55.7
Indian	25.	2	0.1	0.1	0.1
Jawa	26.	11	0.4	0.4	0.3
Kawasaki	28.	234	7.8	7.8	8.1
Moto Guzzi	35.	25	0.8	0.8	0.8
Norton	40.	24	0.8	0.8	0.7
Puch	44.	3	0.1	0.1	0.1
Riverside	46.	3	0.1	0.1	0.1
Sachs	50.	8	0.3	0.3	0.2
Suzuki	54.	148	4.9	4.9	4.4
Triumph	55.	60	2.0	2.0	2.0
Vespa	60.	23	0.8	0.8	0.8
Yamaha	62.	378	12.5	12.5	12.2
Motobecane	65.	22	0.7	0.7	0.4
	TOTAL	3016	100.0	100.0	

TABLE 8.5.11. RIDER SOMATIC INJURIES AND MOTORCYCLE SIZE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Engine Displacement, cc	49.	14	0.5	0.5	0.5
	50.	41	1.4	1.4	1.8
	60.	7	0.2	0.2	2.1
	70.	19	0.6	0.6	2.7
	73.	6	0.2	0.2	2.9
	75.	5	0.2	0.2	3.1
	80.	19	0.6	0.6	3.7
	83.	5	0.2	0.2	3.8
	90.	55	1.8	1.8	5.7
	100.	72	2.4	2.4	8.1
	120.	1	0.0	0.0	8.1
	125.	127	4.2	4.2	12.3
	127.	2	0.1	0.1	12.4
	150.	16	0.5	0.5	12.9
	160.	6	0.2	0.2	13.1
	175.	87	2.9	2.9	16.0
	180.	3	0.1	0.1	16.1
	185.	5	0.2	0.2	16.3
	200.	27	0.9	0.9	17.2
	250.	115	3.8	3.8	21.0
	305.	25	0.8	0.8	21.8
	350.	420	13.9	13.9	35.7
	360.	130	4.3	4.3	40.1
	380.	26	0.9	0.9	40.9
	400.	183	6.1	6.1	47.0
	450.	107	3.5	3.6	50.5
	500.	209	6.9	6.9	57.5
	550.	115	3.8	3.8	61.3
	600.	7	0.2	0.2	61.5
	650.	99	3.3	3.3	64.8
	750.	577	19.1	19.2	84.0
	800.	2	0.1	0.1	84.0
	850.	30	1.0	1.0	85.0
	900.	94	3.1	3.1	88.2
	1000.	107	3.5	3.6	91.7
	1200.	250	8.3	8.3	100.0
Unknown	9998.	3	0.1	Missing	100.0
	TOTAL	3016	100.0	100.0	

These comparisons show that the smaller motorcycles account for slightly less than their fair share of rider somatic injuries, and the larger motorcycles account for slightly more than the accident population and the statistical significance is low.

This slight overrepresentation of the larger motorcycles in somatic injury attribution implies that motorcycle size is only a weak indicator of somatic injury severity, and it is likely that other factors will show a more significant association with injury frequency or severity.

An alternative perspective for the evaluation of motorcycle rider somatic injuries is the selection of the most severe somatic injury in each of the 900 on-scene, in-depth accident cases. For this sort of evaluation, the rider somatic injury of highest severity (highest AIS) is selected for each case and tabulated. Table 8.5.12 shows the body regions for the rider's most severe somatic injuries.

TABLE 8.5.12. RIDER MOST SEVERE SOMATIC INJURY REGION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Upper Arm	A	26	3.0	3.0
Back	B	35	4.0	4.0
Chest	C	52	6.0	6.0
Elbow	E	35	4.0	4.0
Knee	K	113	13.0	13.1
Lower Leg	L	173	20.0	20.0
Abdomen	M	45	5.2	5.2
Whole Body	O	2	0.2	0.2
Pelvic/Hip	P	57	6.6	6.6
Ankel/Foot	Q	86	9.9	9.9
Forearm	R	45	5.2	5.2
Shoulder	S	46	5.3	5.3
Thigh	T	59	6.8	6.8
Wrist/Hand	W	89	10.3	10.3
Upper Extremities	X	1	0.1	0.1
Trunk	Y	2	0.2	0.2
	TOTAL	866	100.0	100.0

Note that this perspective amplifies the significance of lower leg injuries since they are 20.0% of those most severe somatic injuries. Also, from this tabulation note that the sum of hip, thigh, knee, lower leg, and ankle-foot injuries is 56.4% of those most severe rider somatic injuries.

Also, from the evaluation of those data of Table 8.5.12, it is noted that the riders in 34 (3.8%) of the accidents, incurred no somatic injury.

Table 8.5.13 shows that the most severe rider somatic injuries are essentially symmetrical.

Table 8.5.14 shows the type of lesion for the motorcycle rider most severe somatic injury. As in the previous Table 8.5.7, abrasion injuries are most frequent but fractures plus dislocations are 28.1% of the most severe injuries.

TABLE 8.5.13. SIDE OF MOST SEVERE RIDER SOMATIC INJURY (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Bilateral	B	72	8.3	8.3
Central	C	62	7.2	7.2
Left	L	352	40.6	40.6
Right	R	380	43.9	43.9
	TOTAL	866	100.0	100.0

TABLE 8.5.14. RIDER MOST SEVERE SOMATIC INJURY, LESION TYPE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Abrasion	A	231	26.7	26.7
Burn	B	4	0.5	0.5
Contusion	C	155	17.9	17.9
Dislocation	D	20	2.3	2.3
Fracture	F	223	25.8	25.8
Swelling	G	5	0.6	0.6
Hemorrhage	H	4	0.5	0.5
Laceration	L	88	10.2	10.2
Amputation	M	3	0.3	0.3
Crushing	N	3	0.3	0.3
Other	O	1	0.1	0.1
Pain	P	67	7.7	7.7
Rupture	R	6	0.7	0.7
Sprain	S	45	5.2	5.2
Unknown	U	1	0.1	0.1
Avulsion	V	10	1.2	1.2
	TOTAL	866	100.0	100.0

Table 8.5.15 shows the system-organ involved for the rider most severe somatic injuries, and the integument injury dominates with 49.1% of these most severe somatic injuries. Joint and skeletal injuries combine for 37.0% of the total.

Table 8.5.16 shows the severity of the rider most severe somatic injury. Of course, when the "most severe" injuries are analyzed, the more severe levels become relatively more frequent. Compare these data with Table 8.5.9.

TABLE 8.5.15. RIDER MOST SEVERE SOMATIC INJURY, SYSTEM/ORGAN INVOLVED (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Arteries	A	11	1.3	1.4
Digestive	D	1	0.1	0.1
Urogenital	G	22	2.5	2.6
Heart	H	12	1.4	1.5
Integumentary	I	405	46.8	49.1
Joints	J	88	10.2	10.7
Kidney	K	2	0.2	0.2
Liver	L	3	0.3	0.3
Muscles	M	32	3.7	3.9
Nervous System	N	1	0.1	0.1
Pulmonary/Lungs	P	5	0.6	0.6
Spleen	Q	5	0.6	0.6
Respiratory	R	1	0.1	0.1
Skeletal	S	210	24.2	25.4
Unknown	U	40	4.6	Missing
Vertebrae	V	8	0.9	0.9
All Systems in Region	W	20	2.3	2.4
	TOTAL	866	100.0	100.0

TABLE 8.5.16. RIDER MOST SEVERE SOMATIC INJURY SEVERITY (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Minor	1	491	56.7
Moderate	2	183	21.1
Severe	3	107	12.4
Serious	4	54	6.2
Critical	5	20	2.3
Fatal	6	11	1.3
	TOTAL	866	100.0

Table 8.5.17 provides a crosstabulation of the body region and severity for the rider most severe somatic injury. The outstanding feature is the high frequency of chest injury as the most severe injury for critical and fatal injuries.

Table 8.5.18 (Appendix C.4) provides a crosstabulation of the body region and type of lesion for the rider most severe somatic injuries. Note that distribution of the most severe chest injuries with fractures and lacerations predominating. Also, note that abrasions predominate as the most severe somatic injury, except for the lower leg and ankle-foot where fractures predominate.

Single vehicle collisions were 230 (25.6%) of the 900 on-scene, in-depth accident cases. Those single vehicle collisions accounted for 685 (22.8%) of the 3004 discrete somatic injuries identifiable in this distinction. The frequency of all somatic injury in single vehicle accidents is not significantly below that of multiple vehicle accidents. Table 8.5.19 shows these data.

There are expected differences in the frequency of somatic injury in single and multiple vehicle collisions. The asterisks added to the data of Table 8.5.19 illustrate the following differences:

(i) There is an outstanding and significantly higher frequency of lower leg injury in multiple vehicle collisions.

(ii) There is a significantly higher frequency of ankle-foot injury in multiple vehicle collisions.

(iii) There are significantly higher forearm and wrist-hand injuries in single vehicle accidents.

Table 8.5.20 shows the rider somatic injury severity for the single and multiple vehicle collisions. The only significant difference is indicated by the asterisk at the level of AIS:3 for the multiple vehicle collision. This difference between single and multiple vehicle collision somatic injury severity is due to the more frequent severe (AIS:3) lower leg injury occurring in the multiple vehicle accident.

Table 8.5.21 (Appendix C.4) shows the body region of injuries to the passengers involved in the 900 on-scene, in-depth accident cases. These passengers suffered 401 discrete injuries to the body (not including head and neck regions).

Table 8.5.22 (Appendix C.4) shows the side of the passenger somatic injuries, and these injuries are essentially symmetrical.

Table 8.5.23 (Appendix C.4) shows the type of lesion for the 401 discrete somatic injuries of passengers.

Table 8.5.24 (Appendix C.4) shows the system or organ involved in the 401 passenger somatic injuries; Table 8.5.25 (Appendix) shows the severity of those injuries.

Table 8.5.26 shows a crosstabulation of somatic injury body region and injury severity for the passengers involved in the 900 on-scene, in-depth cases. Table 8.5.27 provides that equivalent crosstabulation of somatic injury body

TABLE 8.5.17. RIDER SOMATIC REGION BY INJURY SEVERITY, MOST SEVERE INJURY (OSIDs).

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
A	19	3	3	1	0	0	26
Upper Arm	73.1	11.5	11.5	3.8	0.0	0.0	3.0
	3.9	1.6	2.8	1.9	0.0	0.0	
	2.2	0.3	0.3	0.1	0.0	0.0	
B	29	3	3	0	0	0	35
Back	82.9	8.6	8.6	0.0	0.0	0.0	4.0
	5.9	1.6	2.8	0.0	0.0	0.0	
	3.4	0.3	0.3	0.0	0.0	0.0	
C	6	7	10	2	17	10	52
Chest	11.5	13.5	19.2	3.8	32.7	19.2	6.0
	1.2	3.8	9.3	3.7	85.0	90.9	
	0.7	0.8	1.2	0.2	2.0	1.2	
E	27	5	3	0	0	0	35
Elbow	77.1	14.3	8.6	0.0	0.0	0.0	4.0
	5.5	2.7	2.8	0.0	0.0	0.0	
	3.1	0.6	0.3	0.0	0.0	0.0	
K	80	21	10	2	0	0	113
Knee	70.8	18.6	8.8	1.8	0.0	0.0	13.1
	16.3	11.5	9.3	3.7	0.0	0.0	
	9.2	2.4	1.2	0.2	0.0	0.0	
L	78	33	30	32	0	0	173
Lower Leg	45.1	19.1	17.3	18.5	0.0	0.0	20.0
	15.9	18.0	28.0	59.3	0.0	0.0	
	9.0	3.8	3.5	3.7	0.0	0.0	
M	22	11	4	5	3	0	45
Abdomen	48.9	24.4	8.9	11.1	6.7	0.0	5.2
	4.5	6.0	3.7	9.3	15.0	0.0	
	2.5	1.3	0.5	0.6	0.3	0.0	
O	0	0	0	0	0	1	1
Whole Body	0.0	0.0	0.0	0.0	0.0	100.0	0.1
	0.0	0.0	0.0	0.0	0.0	9.1	
	0.0	0.0	0.0	0.0	0.0	0.1	
P	43	3	9	2	0	0	57
Pelvic Hip	75.4	5.3	15.8	3.5	0.0	0.0	6.6
	8.8	1.6	8.4	3.7	0.0	0.0	
	5.0	0.3	1.0	0.2	0.0	0.0	
Q	36	39	10	1	0	0	86
Ankle Foot	41.9	45.3	11.6	1.2	0.0	0.0	9.9
	7.3	21.3	9.3	1.9	0.0	0.0	
	4.2	4.5	1.2	0.1	0.0	0.0	
R	32	4	3	6	0	0	45
Forearm	71.1	8.9	6.7	13.3	0.0	0.0	5.2
	6.5	2.2	2.8	11.1	0.0	0.0	
	3.7	0.5	0.3	0.7	0.0	0.0	
S	23	13	10	0	0	0	46
Shoulders	50.0	28.3	21.7	0.0	0.0	0.0	5.3
	4.7	7.1	9.3	0.0	0.0	0.0	
	2.7	1.5	1.2	0.0	0.0	0.0	
T	31	17	9	2	0	0	59
Thigh	52.5	28.8	15.3	3.4	0.0	0.0	6.8
	6.3	9.3	8.4	3.7	0.0	0.0	
	3.6	2.0	1.0	0.2	0.0	0.0	
W	63	22	3	1	0	0	89
Wrist-Hand	70.8	24.7	3.4	1.1	0.0	0.0	10.3
	12.9	12.0	2.8	1.9	0.0	0.0	
	7.3	2.5	0.3	0.1	0.0	0.0	
X	0	1	0	0	0	0	1
Upper Extremities	0.0	100.0	0.0	0.0	0.0	0.0	0.1
	0.0	0.5	0.0	0.0	0.0	0.0	
	0.0	0.1	0.0	0.0	0.0	0.0	
Y	1	1	0	0	0	0	2
Trunk	50.0	50.0	0.0	0.0	0.0	0.0	0.2
	0.2	0.5	0.0	0.0	0.0	0.0	
	0.1	0.1	0.0	0.0	0.0	0.0	
Column	490	183	107	54	20	11	865
Total	56.6	21.2	12.4	6.2	2.3	1.3	100.0

TABLE 8.5.19. RIDER SOMATIC INJURIES, BODY REGION
SINGLE AND MULTIPLE VEHICLE COLLISIONS
(OSIDs)

Category Label	Code	Single Vehicle Frequency	Single Vehicle %	Multiple Vehicle Frequency	Multiple Vehicle %	Total
Upper Arm	A	25	3.6	73	3.1	98
Back	B	22	3.2	110	4.7	132
Chest	C	63	9.2	144	6.2	207
Elbow	E	40	5.8	127	5.5	167
Knee	K	102	14.9	329	14.2	431
Lower Leg	L	56	8.2	364 *	15.7	420
Abdomen	M	35	5.1	179	7.7	214
Whole Body	O	2	0.3	3	0.1	5
Pelvic	P	44	6.4	130	5.6	174
Ankle-Foot	Q	47	6.9	209 *	9.0	256
Forearm	R	59 *	8.6	114	4.9	173
Shoulder	S	49	7.2	112	4.8	161
Thigh	T	34	5.0	176	7.6	210
Unknown	U	1	0.1	3	0.1	4
Wrist-Hand	W	103 *	15.0	238	10.3	341
Upper Ext.	X	1	0.1	5	0.2	6
Trunk	Y	2	0.3	3	0.1	5
	TOTAL	685	100.0	2319	100.0	3004

TABLE 8.5.20. RIDER SOMATIC INJURY SEVERITY
SINGLE AND MULTIPLE VEHICLE COLLISIONS
(OSIDs)

Category Label	Single Vehicle Frequency	Single Vehicle %	Multiple Vehicle Frequency	Multiple Vehicle %	Total
AIS: 1 Minor	519	75.8	1737	74.9	2256
2 Moderate	102	14.9	280	12.1	382
3 Severe	34	5.0	180 *	7.8	214
4 Serious	18	2.6	81	3.5	99
5 Critical	10	1.5	30	1.3	40
6 Fatal	2	0.3	10	0.4	12
8 Unknown	0	0	1	0.0	1
TOTAL	685	100.0	2319	100.0	3004

TABLE 8.5.26. PASSENGER SOMATIC INJURY REGION BY INJURY SEVERITY

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
A	11	1	0	0	0	0	12
Upper Arm	91.7	8.3	0.0	0.0	0.0	0.0	3.0
	3.4	2.4	0.0	0.0	0.0	0.0	
	2.7	0.2	0.0	0.0	0.0	0.0	
B	17	1	6	0	1	0	25
Back	68.0	4.0	24.0	0.0	4.0	0.0	6.2
	5.2	2.4	28.6	0.0	33.3	0.0	
	4.2	0.2	1.5	0.0	0.2	0.0	
C	12	1	6	1	0	1	21
Chest	57.1	4.8	28.6	4.8	0.0	4.8	5.2
	3.7	2.4	28.6	10.0	0.0	100.0	
	3.0	0.2	1.5	0.2	0.0	0.2	
E	22	0	0	0	0	0	22
Elbow	100.0	0.0	0.0	0.0	0.0	0.0	5.5
	6.8	0.0	0.0	0.0	0.0	0.0	
	5.5	0.0	0.0	0.0	0.0	0.0	
K	47	1	1	0	0	0	49
Knee	95.9	2.0	2.0	0.0	0.0	0.0	12.2
	14.5	2.4	4.8	0.0	0.0	0.0	
	11.7	0.2	0.2	0.0	0.0	0.0	
L	44	8	4	3	0	0	59
Lower Leg	74.6	13.6	6.8	5.1	0.0	0.0	14.7
	13.6	19.0	19.0	30.0	0.0	0.0	
	11.0	2.0	1.0	0.7	0.0	0.0	
M	12	2	0	4	1	0	19
Abdomen	63.2	10.5	0.0	21.1	5.3	0.0	4.7
	3.7	4.8	0.0	40.0	33.3	0.0	
	3.0	0.5	0.0	1.0	0.2	0.0	
O	0	0	0	0	1	0	1
Whole Body	0.0	0.0	0.0	0.0	100.0	0.0	0.2
	0.0	0.0	0.0	0.0	33.3	0.0	
	0.0	0.0	0.0	0.0	0.2	0.0	
P	17	2	0	0	0	0	19
Pelvic Hip	89.5	10.5	0.0	0.0	0.0	0.0	4.7
	5.2	4.8	0.0	0.0	0.0	0.0	
	4.2	0.5	0.0	0.0	0.0	0.0	
Q	42	10	1	0	0	0	53
Ankle Foot	79.2	18.9	1.9	0.0	0.0	0.0	13.2
	13.0	23.8	4.8	0.0	0.0	0.0	
	10.5	2.5	0.2	0.0	0.0	0.0	
R	23	2	2	2	0	0	29
Forearm	79.3	6.9	6.9	6.9	0.0	0.0	7.2
	7.1	4.8	9.5	20.0	0.0	0.0	
	5.7	0.5	0.5	0.5	0.0	0.0	
S	16	5	0	0	0	0	21
Shoulders	76.2	23.8	0.0	0.0	0.0	0.0	5.2
	4.9	11.9	0.0	0.0	0.0	0.0	
	4.0	1.2	0.0	0.0	0.0	0.0	
T	18	4	1	0	0	0	23
Thigh	78.3	17.4	4.3	0.0	0.0	0.0	5.7
	5.6	9.5	4.8	0.0	0.0	0.0	
	4.5	1.0	0.2	0.0	0.0	0.0	
W	37	5	0	0	0	0	42
Wrist-Hand	88.1	11.9	0.0	0.0	0.0	0.0	10.5
	11.4	11.9	0.0	0.0	0.0	0.0	
	9.2	1.2	0.0	0.0	0.0	0.0	
X	4	0	0	0	0	0	4
Upper Extremities	100.0	0.0	0.0	0.0	0.0	0.0	1.0
	1.2	0.0	0.0	0.0	0.0	0.0	
	1.0	0.0	0.0	0.0	0.0	0.0	
Y	1	0	0	0	0	0	1
Trunk	100.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.3	0.0	0.0	0.0	0.0	0.0	
	0.2	0.0	0.0	0.0	0.0	0.0	
8	1	0	0	0	0	0	1
	100.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.3	0.0	0.0	0.0	0.0	0.0	
	0.2	0.0	0.0	0.0	0.0	0.0	
Column	324	42	21	10	3	1	401
Total	80.8	10.5	5.2	2.5	0.7	0.2	100.0

TABLE 8.5.27. RIDER SOMATIC INJURY REGION BY INJURY SEVERITY

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
A	75	15	6	2	0	0	0	98
Upper Arm	76.5	15.3	6.1	2.0	0.0	0.0	0.0	3.3
	3.3	3.9	2.8	2.0	0.0	0.0	0.0	
	2.5	0.5	0.2	0.1	0.0	0.0	0.0	
B	112	11	9	0	0	0	0	132
Back	84.8	8.3	6.8	0.0	0.0	0.0	0.0	4.4
	5.0	2.9	4.2	0.0	0.0	0.0	0.0	
	3.7	0.4	0.3	0.0	0.0	0.0	0.0	
C	85	22	47	13	28	11	0	206
Chest	41.3	10.7	22.8	6.3	13.6	5.3	0.0	6.8
	3.8	5.7	21.8	13.1	70.0	91.7	0.0	
	2.8	0.7	1.6	0.4	0.9	0.4	0.0	
E	158	5	5	0	0	0	0	168
Elbow	94.0	3.0	3.0	0.0	0.0	0.0	0.0	5.6
	7.0	1.3	2.3	0.0	0.0	0.0	0.0	
	5.2	0.2	0.2	0.0	0.0	0.0	0.0	
K	375	42	13	2	0	0	0	432
Knee	86.8	9.7	3.0	0.5	0.0	0.0	0.0	14.3
	16.6	10.9	6.0	2.0	0.0	0.0	0.0	
	12.4	1.4	0.4	0.1	0.0	0.0	0.0	
L	295	53	41	34	0	0	1	424
Lower Leg	69.6	12.5	9.7	8.0	0.0	0.0	0.2	14.1
	13.0	13.8	19.0	34.3	0.0	0.0	100.0	
	9.8	1.8	1.4	1.1	0.0	0.0	0.0	
M	136	22	14	33	10	0	0	215
Abdomen	63.3	10.2	6.5	15.3	4.7	0.0	0.0	7.1
	6.0	5.7	6.5	33.3	25.0	0.0	0.0	
	4.5	0.7	0.5	1.1	0.3	0.0	0.0	
O	2	2	0	0	0	1	0	5
Whole Body	40.0	40.0	0.0	0.0	0.0	20.0	0.0	0.2
	0.1	0.5	0.0	0.0	0.0	8.3	0.0	
	0.1	0.1	0.0	0.0	0.0	0.0	0.0	
P	141	15	16	3	1	0	0	176
Pelvic Hip	80.1	8.5	9.1	1.7	0.6	0.0	0.0	5.8
	6.2	3.9	7.4	3.0	2.5	0.0	0.0	
	4.7	0.5	0.5	0.1	0.0	0.0	0.0	
Q	171	68	16	1	0	0	0	256
Ankle Foot	66.8	26.6	6.3	0.4	0.0	0.0	0.0	8.5
	7.6	17.7	7.4	1.0	0.0	0.0	0.0	
	5.7	2.3	0.5	0.0	0.0	0.0	0.0	
R	145	14	7	8	0	0	0	174
Forearm	83.3	8.0	4.0	4.6	0.0	0.0	0.0	5.8
	6.4	3.6	3.2	8.1	0.0	0.0	0.0	
	4.8	0.5	0.2	0.3	0.0	0.0	0.0	
S	116	29	16	0	0	0	0	161
Shoulders	72.0	18.0	9.9	0.0	0.0	0.0	0.0	5.3
	5.1	7.6	7.4	0.0	0.0	0.0	0.0	
	3.8	1.0	0.5	0.0	0.0	0.0	0.0	
T	159	32	17	2	1	0	0	211
Thigh	75.4	15.2	8.1	0.9	0.5	0.0	0.0	7.0
	7.0	8.3	7.9	2.0	2.5	0.0	0.0	
	5.3	1.1	0.6	0.1	0.0	0.0	0.0	
U	3	1	0	0	0	0	0	4
Unknown	75.0	25.0	0.0	0.0	0.0	0.0	0.0	0.1
	0.1	0.3	0.0	0.0	0.0	0.0	0.0	
	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
W	281	50	9	1	0	0	0	341
Wrist-Hand	82.4	14.7	2.6	0.3	0.0	0.0	0.0	11.3
	12.4	13.0	4.2	1.0	0.0	0.0	0.0	
	9.3	1.7	0.3	0.0	0.0	0.0	0.0	
X	5	1	0	0	0	0	0	6
Upper Extremities	83.3	16.7	0.0	0.0	0.0	0.0	0.0	0.2
	0.2	0.3	0.0	0.0	0.0	0.0	0.0	
	0.2	0.0	0.0	0.0	0.0	0.0	0.0	
Y	3	2	0	0	0	0	0	5
Trunk	60.0	40.0	0.0	0.0	0.0	0.0	0.0	0.2
	0.1	0.5	0.0	0.0	0.0	0.0	0.0	
	0.1	0.1	0.0	0.0	0.0	0.0	0.0	
Column	2262	384	216	99	40	12	1	3014
Total	75.0	12.7	7.2	3.3	1.3	0.4	0.0	100.0

region and injury severity for the motorcycle riders of the 900 on-scene, in-depth accident cases. Of course there are considerable similarities between the passenger and rider somatic injury data, and this is expected because of essentially equivalent exposure to injury surfaces. However, the differences outstanding in these data are as follows:

(i) Passengers suffer relatively less frequent ankle-foot and abdominal injury.

(ii) Passengers suffer relatively less frequent lacerations but more abrasions.

(iii) Passengers suffer less frequent urogenital injuries.

These differences are expected in some ways since the motorcycle rider usually precedes the passenger into the collision impact area, and the passenger can expect some benefit at the expense of the motorcycle rider.

8.6 Head and Neck Injuries

A separate file was prepared and maintained for the head and neck injury data. This separation of head and neck injury data from the somatic injury data was necessary so that special attention could be given to the more complex details typical of head and neck injury. In these data, head and neck injury data include face injury data.

One source of head and neck injury data was the 3600 traffic accident report cases. Table 8.6.1 shows the data for motorcycle rider head and neck injuries collected from analysis of the traffic accident report cases. Table 8.6.2 shows the equivalent data collected for the passengers involved in those 3600 traffic accident report cases. These data show a distinction between head and neck and face injury so that the total injury to the head (including face) and neck will be equal to or less than the sum of the two injury data elements. Table 8.6.1 shows that the highest frequency of head (and face) and neck injury for the accident-involved motorcycle riders would be 35.8%; Table 8.6.2 shows that the highest frequency of head and neck injury for the accident-involved passengers would be 31.4%.

The head and neck injury data collected for the motorcycle riders in the 900 on-scene, in-depth cases showed a total of 861 discrete injuries to the head and neck regions. The most outstanding feature of these injury data is that those motorcycle riders wearing helmets (39.8% of the accident-involved motorcycle riders) had far less than their fair share of head and neck injuries (22.8%).

Table 8.6.3 shows the region of the head and neck where the 861 injuries were located. A special feature of these injuries is the expected dominance of the forward orientation of the injuries; the sum of frontal, face-general, mandible, nasal, orbit, sphenoid, maxilla, and zygoma regions injuries is 52.0%. The frontal region is the most frequently involved region, and is that region which could be protected by a safety helmet. The regions of face-general, mandible, nasal, orbit, sphenoid, maxilla and zygoma could be protected only with the forward structure of a full facial coverage safety helmet.

TABLE 8.6.1. MOTORCYCLE RIDER HEAD AND NECK INJURIES (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>Head Neck Injury</u>				
None	0.	2497	69.4	79.4
Yes	1.	649	18.0	20.6
Unknown-Not Reported	8.	454	12.6	Missing
	TOTAL	3600	100.0	100.0
<u>Face Injury</u>				
None	0.	2657	73.8	84.8
Yes	1.	477	13.2	15.2
Unknown-Not Reported	8.	466	12.9	Missing
	TOTAL	3600	100.0	100.0

TABLE 8.6.2. MOTORCYCLE PASSENGER HEAD AND NECK INJURIES (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>MC Passenger Head/Neck Injury</u>				
None	0.	361	10.0	77.6
Yes	1.	104	2.9	22.4
Unknown-Not Reported	8.	91	2.5	Missing
N.A.-No Passenger	9.	3044	84.6	Missing
	TOTAL	3600	100.0	100.0
<u>MC Passenger Face Injury</u>				
None	0.	423	11.7	91.0
Yes	1.	42	1.2	9.0
Unknown-Not Reported	8.	91	2.5	Missing
N.A.-No Passenger	9.	3044	84.6	Missing
	TOTAL	3600	100.0	100.0

TABLE 8.6.3. RIDER HEAD AND NECK INJURY REGION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>Head-Neck Region</u>				
Basal	B	39	4.5	4.5
Cervical-General	C	81	9.4	9.4
Frontal	F	119	13.8	13.8
Foramen Magnum	H	1	0.1	0.1
Face-General	K	48	5.6	5.6
Mandible	M	99	11.5	11.5
Nasal	N	49	5.7	5.7
Occipital	O	51	5.9	5.9
Parietal	P	61	7.1	7.1
Brain-General	Q	103	12.0	12.0
Orbit	R	48	5.6	5.6
Sphenoid	S	1	0.1	0.1
Temporal	T	44	5.1	5.1
Unknown	U	8	0.9	0.9
Whole Region	W	4	0.5	0.5
Maxilla	X	40	4.6	4.7
Throat	Y	6	0.7	0.7
Zygoma	Z	43	5.0	5.0
Cervical Vertebra	1	8	0.9	0.9
Cervical Vertebra	2	2	0.2	0.2
Cervical Vertebra	5	2	0.2	0.2
Cervical Vertebra	6	2	0.2	0.2
Cervical Vertebra	7	1	0.1	0.1
None-N.A.	0	1	0.1	Missing
	TOTAL	861	100.0	100.0

Table 8.6.4 shows the side of the motorcycle rider head and neck injury for the 900 on-scene, in-depth accident cases. These data show that the injuries are essentially symmetrical and there is no significant tendency to right or left side injury.

Table 8.6.5 shows the type of lesion for the motorcycle rider head and neck injury for the 900 accident cases. Note that lacerations (23.9%) are most frequent, followed by abrasions (18.4%) fractures (15.7%) and concussions (10.3%).

Table 8.6.6 shows the system-organ involved in the 861 motorcycle rider head and neck injuries. Note that the <u>integumentary</u> injuries, such as lacerations, abrasions, and contusions of the skin of the head and neck, dominate as 55.7% of those 861 injuries. This fact clearly exposes the prospect of protection by the use of a safety helmet. Any qualified safety helmet could attenuate or prevent lacerations and abrasions of the covered regions. This sort of protection would represent the minimum capability of any contemporary safety helmet.

TABLE 8.6.4. RIDER HEAD AND NECK INJURY SIDE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Side				
Bilateral	B	251	29.2	30.3
Central	C	131	15.2	15.8
Left	L	212	24.6	25.5
	M	1	0.1	0.1
Right	R	236	27.4	28.4
Unknown	U	30	3.5	0.0
	TOTAL	861	100.0	100.0

TABLE 8.6.5. RIDER HEAD AND NECK INJURY — TYPE OF LESION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Lesion				
Abrasion	A	158	18.4	18.4
Burn	B	2	0.2	0.2
Contusion	C	84	9.8	9.8
Dislocation	D	2	0.2	0.2
Fracture	F	135	15.7	15.7
Swelling	G	4	0.5	0.5
Hemorrhage	H	38	4.4	4.4
Hematoma	J	44	5.1	5.1
Concussion	K	89	10.3	10.3
Laceration	L	206	23.9	23.9
Amputation	M	2	0.2	0.2
Crushing	N	3	0.3	0.3
Other	O	1	0.1	0.1
Pain	P	61	7.1	7.1
Maceration	Q	4	0.5	0.5
Rupture	R	4	0.5	0.5
Sprain	S	10	1.2	1.2
Herniation	T	1	0.1	0.1
Unknown	U	1	0.1	0.0
Avulsion	V	12	1.4	1.4
	TOTAL	861	100.0	100.0

TABLE 8.6.6. RIDER HEAD AND NECK INJURIES — SYSTEM/ORGAN INVOLVED (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Arteries	A	4	0.5	0.5
Pons-Medulla	B	12	1.4	1.5
Cerebellum	C	6	0.7	0.7
Dural-Extradural	D	7	0.8	0.8
Integumentary	I	452	52.5	55.7
Joints	J	4	0.5	0.5
Auditory Apparatus	K	1	0.1	0.1
Larynx-Trachea-Esophagus	L	1	0.1	0.1
Muscles	M	24	2.8	3.0
Neural Tissues	N	112	13.0	13.8
Oral Soft Tissues	O	12	1.4	1.5
Piarachnoid-Subdural	P	19	2.2	2.3
Spinal Cord	Q	1	0.1	0.1
Skeletal	S	120	13.9	14.8
Teeth	T	18	2.1	2.2
Unknown	U	50	5.8	Missing
Vertebra	V	1	0.1	0.1
All Systems in Region	W	13	1.5	1.6
Eye	Y	1	0.1	0.1
Subcortical Structure	Z	3	0.3	0.3
	TOTAL	861	100.0	100.0

While there were 48 injuries in the region of the orbit (Table 8.6.3), there was only 1 injury to the eye itself. Consequently, these data relate no significant requirement for physical protection of the eye! The use of glasses, goggles and face shields is most essential in the protection from wind blast to preserve vision; the mechanical protection from collision injury is not a significant factor.

Injuries to the central nervous system accounted for 18.5% of all the head and neck injuries, and architectural injuries accounted for 14.5%. Of course, these are the injuries of greater severity and can be reduced or prevented only by location of an energy absorbing medium at the impact site.

Table 8.6.7 shows the severity of the 861 head and neck injuries. The critical and fatal injuries were 8.4% of the total, indicating the vulnerability of the head and neck compared to the somatic regions.

Table 8.6.8 shows a crosstabulation of head and neck region and injury severity for the 861 rider injuries. The injuries to areas that are closely associated with the central nervous system indicate the far greater contribution to the serious critical and fatal injuries. On the other hand, the injuries to areas that are remote to the central nervous system have an insignificant contribution to those serious, critical and fatal head and neck injuries. For example, note the high frequency of critical and fatal injury at the first cervical vertebrae (C1)

TABLE 8.6.7. RIDER HEAD AND NECK INJURY SEVERITY
(OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Minor	1	572	66.4	66.4	66.4
Moderate	2	112	13.0	13.0	79.4
Severe	3	74	8.6	8.6	88.0
Serious	4	30	3.5	3.5	91.5
Critical	5	49	5.7	5.7	97.2
Fatal	6	23	2.7	2.7	99.9
Unknown	8	1	0.1	0.1	100.0
	TOTAL	861	100.0	100.0	

but no contribution at the other locations (C2, C5, C6 and C7). Also note that the basal, occipital, temporal, parietal, frontal and brain-general regions have high frequency of serious, critical and fatal injury because those areas are within or immediately adjacent to the extremely vulnerable central nervous system. The injuries to the face-general, mandible, nasal, maxilla, zygoma and orbit show ZERO contribution to serious, critical and fatal injuries. In words, the plastic surgeon can provide repair to non-lethal facial injuries but the neurosurgeon can only limit the life-threatening injuries to the central nervous system.

In actuality, there is a deadly interaction between the recorded non-lethal facial injuries and the life-threatening injuries to the central nervous system. If the motorcycle rider suffers a severe impact to the point of the jaw, the result could be a displaced fracture of the mandible (AIS:3). In addition, and remote from the point of impact, the transmission of force through the mandible could produce a displaced basal skull fracture with laceration of the base of the brain (AIS:5) or brain stem contusion (AIS:5).

Additional perspective of motorcycle rider head and neck injury can be obtained by examination of the most severe head and neck injury in each accident. Table 8.6.9 shows the most severe head and neck injury for the motorcycle riders in the 900 on-scene, in-depth accident cases. In 508 cases, the motorcycle rider did not have any head or neck injury, the extreme of which is shown in Table 8.6.9. Here the most frequent, most severe injury is that region of the brain-general, 19.1%, and the second most frequent is the frontal region. Of course both regions could be protected by a qualified safety helmet.

Table 8.6.10 shows the side of the most severe head and neck injury. In these data the most severe injuries are not symmetrical, and there is a significant excess of right side injuries. The cause of this asymmetry of data is unknown, and explanation is not readily available from review of these data.

Table 8.6.11 shows the type of lesion for that most severe head and neck injury. In these data, the lacerations still are the dominant injury but concussion is now the second ranking injury in this perspective of injuries.

TABLE 8.6.8. RIDER HEAD AND NECK INJURY REGION BY SEVERITY

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
B	0	0	22	6	8	3	0	39
Basal	0.0	0.0	56.4	15.4	20.5	7.7	0.0	4.5
	0.0	0.0	29.7	20.0	16.7	13.0	0.0	
	0.0	0.0	2.6	0.7	0.9	0.3	0.0	
C	73	2	2	0	2	2	0	81
Cervical-General	90.1	2.5	2.5	0.0	2.5	2.5	0.0	9.4
	12.8	1.8	2.7	0.0	4.2	8.7	0.0	
	8.5	0.2	0.2	0.0	0.2	0.2	0.0	
F	102	5	0	5	3	4	0	119
Frontal	85.7	4.2	0.0	4.2	2.5	3.4	0.0	13.8
	17.8	4.5	0.0	16.7	6.3	17.4	0.0	
	11.9	0.6	0.0	0.6	0.3	0.5	0.0	
H	0	0	0	0	0	1	0	1
Foramen Magnum	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.1
	0.0	0.0	0.0	0.0	0.0	4.3	0.0	
	0.0	0.0	0.0	0.0	0.0	0.1	0.0	
K	46	2	0	0	0	0	0	48
Face-General	95.8	4.2	0.0	0.0	0.0	0.0	0.0	5.6
	8.0	1.8	0.0	0.0	0.0	0.0	0.0	
	5.3	0.2	0.0	0.0	0.0	0.0	0.0	
M	78	17	4	0	0	0	0	99
Mandible	78.8	17.2	4.0	0.0	0.0	0.0	0.0	11.5
	13.6	15.2	5.4	0.0	0.0	0.0	0.0	
	9.1	2.0	0.5	0.0	0.0	0.0	0.0	
N	40	9	0	0	0	0	0	49
Nasal	81.6	18.4	0.0	0.0	0.0	0.0	0.0	5.7
	7.0	8.0	0.0	0.0	0.0	0.0	0.0	
	4.7	1.0	0.0	0.0	0.0	0.0	0.0	
O	28	5	9	1	8	0	0	51
Occipital	54.9	9.8	17.6	2.0	15.7	0.0	0.0	5.9
	4.9	4.5	12.2	3.3	16.7	0.0	0.0	
	3.3	0.6	1.0	0.1	0.9	0.0	0.0	
P	27	14	8	5	5	2	0	61
Parietal	44.3	23.0	13.1	8.2	8.2	3.3	0.0	7.1
	4.7	12.5	10.8	16.7	10.4	8.7	0.0	
	3.1	1.6	0.9	0.6	0.6	0.2	0.0	
Q	31	35	12	4	17	4	0	103
Brain-General	30.1	34.0	11.7	3.9	16.5	3.9	0.0	12.0
	5.4	31.3	16.2	13.3	35.4	17.4	0.0	
	3.6	4.1	1.4	0.5	2.0	0.5	0.0	
R	40	3	5	0	0	0	0	48
Orbit	83.3	6.3	10.4	0.0	0.0	0.0	0.0	5.6
	7.0	2.7	6.8	0.0	0.0	0.0	0.0	
	4.7	0.3	0.6	0.0	0.0	0.0	0.0	
S	0	0	0	1	0	0	0	1
Sphenoid	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.1
	0.0	0.0	0.0	3.3	0.0	0.0	0.0	
	0.0	0.0	0.0	0.1	0.0	0.0	0.0	
Column	572	112	74	30	48	23	1	860
Total	66.5	13.0	8.6	3.5	5.6	2.7	0.1	100.0

Continued

TABLE 8.6.8 (continued)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
T Temporal	27 61.4 4.7 3.1	5 11.4 4.5 0.6	4 9.1 5.4 0.5	4 9.1 13.3 0.5	3 6.8 6.3 0.3	1 2.3 4.3 0.1	0 0.0 0.0 0.0	44 5.1
U Unknown	4 50.0 0.7 0.5	1 12.5 0.9 0.1	0 0.0 0.0 0.0	2 25.0 6.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 12.5 100.0 0.1	8 0.9
W Whole Region	2 50.0 0.3 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 25.0 3.3 0.1	0 0.0 0.0 0.0	1 25.0 4.3 0.1	0 0.0 0.0 0.0	4 0.5
X Maxilla	32 80.0 5.6 3.7	8 20.0 7.1 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	40 4.7
Y Throat	2 33.3 0.3 0.2	2 33.3 1.8 0.2	1 16.7 1.4 0.1	1 16.7 3.3 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 0.7
Z Zygoma	39 90.7 6.8 4.5	4 9.3 3.6 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	43 5.0
1 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 12.5 1.4 0.1	0 0.0 0.0 0.0	2 25.0 4.2 0.2	5 62.5 21.7 0.6	0 0.0 0.0 0.0	8 0.9
2 Cervical Vertebra	1 50.0 0.2 0.1	0 0.0 0.0 0.0	1 50.0 1.4 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
5 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 2.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
6 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 2.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
7 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 1.4 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.1
Column Total	572 66.5	112 13.0	74 8.6	30 3.5	48 5.6	23 2.7	1 0.1	860 100.0

TABLE 8.6.9. RIDER MOST SEVERE HEAD AND NECK INJURY REGION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Basal	B	8	0.9	2.1
Cervical-General	C	36	4.0	9.3
Frontal	F	66	7.3	17.1
Foramen Magnum	H	1	0.1	0.3
Face-General	K	11	1.2	2.8
Mandible	M	40	4.4	10.3
Nasal	N	27	3.0	7.0
Occipital	O	24	2.7	6.2
Parietal	P	31	3.4	8.0
Brain-General	Q	74	8.2	19.1
Orbit	R	18	2.0	4.7
Temporal	T	22	2.4	5.7
Whole Region	W	1	0.1	0.3
Maxilla	X	6	0.7	1.6
Zygoma	Z	14	1.6	3.6
Cervical Vertebra	1	6	0.7	1.6
Cervical Vertebra	2	1	0.1	0.3
Cervical Vertebra	6	1	0.1	0.3
Unknown	U	5	0.6	Missing
None-N.A.	0	508	56.4	Missing
	TOTAL	900	100.0	100.0

TABLE 8.6.10. RIDER MOST SEVERE HEAD AND NECK INJURY SIDE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Bilateral	B	124	13.8	32.9
Central	C	58	6.4	15.4
Left	L	78	8.7	20.7
Midline	M	1	0.1	0.3
Right	R	116	12.9	30.8
Unknown	U	15	1.7	Missing
None-N.A.	0	508	56.4	Missing
	TOTAL	900	100.0	100.0

TABLE 8.6.11. RIDER MOST SEVERE HEAD AND NECK INJURY — TYPE OF LESION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Abrasion	A	66	7.3	16.9
Burn	B	1	0.1	0.3
Contusion	C	27	3.0	6.9
Fracture	F	40	4.4	10.2
Hemorrhage	H	17	1.9	4.3
Hematoma	J	26	2.9	6.6
Concussion	K	67	7.4	17.1
Laceration	L	95	10.6	24.3
Amputation	M	1	0.1	0.3
Crushing	N	2	0.2	0.5
Other	O	1	0.1	0.3
Pain	P	34	3.8	8.7
Maceration	Q	3	0.3	0.8
Rupture	R	1	0.1	0.3
Sprain	S	3	0.3	0.8
Herniation	T	1	0.1	0.3
Avulsion	V	6	0.7	1.5
Unknown	U	1	0.1	Missing
None-N.A.	0	508	56.4	Missing
	TOTAL	900	100.0	100.0

Table 8.6.12 shows the system/organ involved in those 492 cases with most severe head and neck injury. Integumentary injuries still dominate as 55.4% of those 492 most severe injuries.

Table 8.6.13 shows the severity of the most severe head and neck injuries. Here the critical and fatal injuries are 5.4% of the total of most severe head and neck injuries.

The passengers involved in the 900 on-scene, in-depth accident cases received a total of 136 discrete head and neck injuries. The helmet use for the accident involved passengers was far below that of the motorcycle riders. 39.6% of the riders wore helmets but only 9.6% of the passengers wore helmets. Also passengers were present in 17.1% of the accidents but their injury frequency was 15.8%. In many accident configurations the passenger is somewhat protected by the rider, and the rider tends to absorb some of those frontal impacts.

Table 8.6.14 (Appendix C.4) shows the head and neck region of the 136 injuries to the passengers. Approximately half of these injuries have the forward orientation of frontal impact. Table 8.6.15 (Appendix C.4) shows the passenger head and neck injuries to be approximately symmetrical. Table 8.6.16 (Appendix C.4) shows the type of lesion for the passenger head and neck injuries, and abrasions are most frequent. Table 8.6.17 (Appendix C.4) shows the system-organ involved for the

TABLE 8.6.12. RIDER MOST SEVERE HEAD AND NECK INJURY — SYSTEM/ORGAN (OSIDs)

Category Level	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Arteries	A	1	0.1	0.3
Pons-Medulla	B	7	0.8	1.9
Cerebellum	C	2	0.2	0.6
Dural-Extradural	D	2	0.2	0.6
Integumentary	I	200	22.2	55.4
Joints	J	1	0.1	0.3
Auditory Apparatus	K	1	0.1	0.3
Muscles	M	9	1.0	2.5
Neural Tissues	N	79	8.8	21.9
Oral Soft Tissues	O	3	0.3	0.8
Piarachnoid-Subdural	P	11	1.2	3.0
Skeletal	S	36	4.0	10.0
Teeth	T	2	0.2	0.6
All Systems in Region	W	6	0.7	1.7
Subcortical Structure	Z	1	0.1	0.3
Unknown	U	31	3.4	Missing
None	0	508	56.4	Missing
	TOTAL	900	100.0	100.0

TABLE 8.6.13. RIDER MOST SEVERE HEAD AND NECK INJURY SEVERITY (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0	508	56.4	56.5	56.5
Minor	1	256	28.4	28.5	85.0
Moderate	2	59	6.6	6.6	91.5
Severe	3	18	2.0	2.0	93.5
Serious	4	9	1.0	1.0	94.5
Critical	5	29	3.2	3.2	97.8
Fatal	6	20	2.2	2.2	100.0
Unknown	8	1	0.1	Missimg	100.0
	TOTAL	900	100.0	100.0	

passenger head and neck injuries, and integument injuries dominate with 57.5%. Table 8.6.18 (Appendix C.4) provides a crosstabulation of passenger head and neck injury region and injury severity. The characteristics are generally similar to the rider head and neck injury severity patterns.

8.7 Injury Mechanisms

The most important factors in the mechanism of injury are the contact surfaces, which were identified in the analysis of the discrete injuries for the 900 on-scene, in-depth accident cases. For example, an automobile turns left in front of the oncoming motorcycle and the rider's lower left leg is trapped in impact between the automobile front bumper and the motorcycle engine-transmission cases. The resulting injury to the left lower leg would be analyzed and described for data purposes by body region, side, aspect, lesion, and severity. Also, the contact surfaces which are responsible for that injury are described for data purposes, e.g. the car front bumper (CF01) and the motorcycle engine-transmission cases (MC22) so that the injury mechanism is thus defined. In this way it is possible for one, or two, surfaces to be associated with each discrete injury. In the analysis of the 3016 motorcycle rider somatic injuries, 5067 contact surfaces were identified; in the analysis of the 861 motorcycle rider head and neck injuries, 1290 contact surfaces were identified.

Table 8.7.1 (Appendix C.4) shows the codes used to identify the contact surfaces of the vehicles and environment.

Table 8.7.2 (Appendix C.4) shows the frequency of the various contact codes related to the 5067 contact surfaces causing the motorcycle rider somatic injuries. These tables list the following data:

Motorcycles:	1961 contact surfaces	
Other Vehicles:	1421 contact surfaces	
Autos:		1265 contact surfaces
Pickup Trucks:		70 contact surfaces
Large Trucks:		48 contact surfaces
Buses:		1 contact surface
Vans:		37 contact surfaces
Environment:	1668 contact surfaces	
Unknown	17 contact surfaces	
TOTAL	5067 contact surfaces	

Table 8.7.2a shows the 1961 motorcycle contact surfaces related to the rider somatic injuries. It should be noted here that these surfaces identified as injury agents are not necessarily dangerous or wicked surfaces. In great part, the participating surfaces were present simply as the surface adjacent to the injured area. In other words, a nice smooth gas tank is a relatively "friendly" surface until it impacts the genitals in a crash. However, a gas tank with sharp corners and edges or a protruding flip-up type tank cap can cause injuries far more serious than any smooth, compliant surface. But in any case, it will be likely that the gas tank can participate as an injury contact surface. Table 8.7.2a shows that the gas tank (MC02) acted as an injury surface 321 times, 6.3% of the rider somatic injuries. In most of these cases the smooth surface did not aggravate the injuries beyond the expected contusions, abrasions, etc. In a few cases the protruding gas tank cap

exaggerated the injury, especially if the forward-hinged, flip-up type tank cap opened to provide a sharp lacerating surface and also spill fuel.

A soft metal tank side is relatively friendly to the knees of a motorcycle rider. In many instances, the participation of the fuel tank in knee injury was favorable, with the tank thereby denting and absorbing some part of knee impact from another outside surface. In general, the smooth metal gas tank with recessed tank cap did not participate in the exaggeration of rider somatic injuries.

The motorcycle handlebars acted as the most frequent motorcycle injury agent, 869 times or 17.2% of the rider somatic injuries. The dynamics of most motorcycle accident configurations make it very likely that the handlebars will participate as an injury contact surface. Sometimes this participation is at a low level, as in thigh contusions as the rider vaults forward in a frontal impact; some rare times this participation is at a high level when the handlebar end pierces the chest. There is a real contrast between the requirement for the control function and the crashworthiness of handlebars. Accurate and precise control requires rigid handlebars, but crashworthiness favors flexible or movable handlebars. Ideally, the handlebars are stiff and rigid for control operations but upon crash impact the handlebars should fold, rotate, bend, flex or twist to reduce injury contribution. In general, the shorter, more rigid handlebars, e.g., drag bars, contributed more in injury causation when they were so involved. The more flexible handlebars, e.g., six-bend high-rise pullbacks, contributed notably <u>less</u> in injury causation when they were so involved. The high-rise handlebars were then more likely to rotate in the clamps and provide less resistance when impact forces were applied in a crash.

The windshield (MC07) and the fairing (MC17) participated as somatic injury contact surfaces 73 times. It was extremely rare that the fairing or windshield was an active agent of injury. In most cases the fairing or windshield acted simply as a <u>replacement surface</u>, i.e., the motorcycle rider hits the windshield which is against the side of the involved automobile.

Motorcycle mirrors (MC09) acted as injury agents 47 times, and were outstanding only when sharp edges or posts were exposed and clamp-on accessories.

The rear suspension (MC12) participated as an injury surface 90 times, primarily by the rear shock absorber-spring set acting as the inside surface contacting the knee, lower leg, or ankle-foot. The turn signals (MC21) were the injury agents 37 times in the same way by the protrusion of the rear turn signals on rigid stalks or mounting brackets. The more modern flexible stalk mountings were seen during several accident investigations but there was <u>no</u> instance of injury contribution of that flexible mounting and that design configuration seems very crashworthy.

The motorcycle engine-transmission cases (MC22) acted as the injury contact surface 256 times. In general, this contact surface was one of two surfaces producing injury to the lower leg and ankle-foot. For examples, in an angle collision the rider's ankle-foot and lower leg would be trapped in contact between the automobile rear corner and the motorcycle engine-transmission side, or in a slide-out and fall the rider's ankle-foot and lower leg would be trapped in contact between the pavement and the motorcycle engine-transmission side. A notable exception

where the motorcycle engine-transmission did not participate in such injury was the engine configuration with horizontally opposed cylinders, e.g. BMW (see section 6.12, Crash Bar Effectiveness).

Motorcycle batteries did not contribute as injury agents; only the sharp edges of the battery side cover participated as an injury agent in 3 instances.

Table 8.7.2b shows the automobile contact surfaces related to the motorcycle somatic injuries. The front surfaces and front sides of the cars forward of the front wheel account for half of the somatic injury contact surfaces. The rear and rear corners of the automobile account for 11.4% of the somatic injuries.

Table 8.7.2c shows the rider somatic injury contact surfaces for the pickup, truck, bus and van involvement.

Table 8.7.2d shows the rider somatic injury contact surfaces contributed by the environment. Note that the pavement (EA01, EC01) contributes 1384 or 82.9% of the total injury surfaces from the environment.

Table 8.7.3 (Appendix C.4) shows the cross-tabulation of the contact surface with the body region of the rider somatic injuries. The application of these data explains the function of the contact surfaces in generating the region injury. For example, the car front bumper (CF01) is specially associated with injuries to the lower leg and ankle-foot, 100 of the 139 contact surfaces are with those body regions and the results were usually severe. Note that the gas tank, MC02, has the highest association with those body regions close to it; the knee (75), thigh (52), and abdomen (115) associate most frequently, and the abdomen is entirely that inferior aspect involving urogenital injury.

Table 8.7.4 (Appendix C.4) shows the cross-tabulation of the contact surface with the injury severity for the rider somatic injuries. The application of these data explains the function of the contact surfaces in generating severe injury. The essential facts presented here are that rigid, sharp surfaces do in fact generate the more severe injuries. A special perspective is available by examining the contact surfaces most frequently involved at AIS≥3, i.e. severe, serious, critical and fatal injuries. The following data illustrate that involvement for some identifiable rigid surfaces:

Contact Surface	AIS ≥ 3
Front Bumper (CF01, PF01, VF01)	41
Front Corner (CF03, CS03, etc.)	68
Pavement, Curb (EA01, EC01, EC06)	55
Trees, Poles, Barriers, Guardrails (EW02, EW04, EM02, EM04)	59
Motorcycle Rigid Metal Parts (MC02, MC03, MC05, MC06, MC07, MC12, MC20, MC22)	207
TOTAL	430

These data show that the participation of the motorcycle rigid surfaces is approximately half of the total, and the other vehicles and environment contribute their half. In other words, the two agents participating in the accident process seem to contribute their approximate share of the more severe rider somatic injuries.

Table 8.7.5 (Appendix C.4) shows the frequency of the various contact codes related to the 1290 contact surfaces causing the rider head and neck injuries. These tables list the following data:

Motorcycles:	91 contact surfaces
Other Vehicles:	471 contact surfaces
Autos:	403 contact surfaces
Pickups:	29 contact surfaces
Trucks:	19 contact surfaces
Buses:	2 contact surfaces
Vans:	18 contact surfaces
Environment:	721 contact surfaces
Others, Unknown	7 contact surfaces
TOTAL	1290 contact surfaces

Table 8.7.5a shows the 91 motorcycle contact surfaces related to the rider head and neck injuries. Note that the windshield (MC07) and fairing (MC17) participated as head and neck injury surfaces a total of 24 times, and the participation was essentially identical to that of the somatic injuries. It was extremely rare that the windshield or fairing was an active agent of injury, the surface acted mostly as a replacement for the participating other vehicle or environment. The handlebars (MC05) were the most frequent surface of the motorcycle acting as an agent of injury to the rider head and neck.

There are four cases noted where the motorcycle safety helmet (MC38) participated as the injury surface. All four cases involved only minor, "Band-aid" type injuries to the nose (2), jaw (1) and neck (1) when a severe impact occurred at some other location on the helmet.

Table 8.7.5b shows the 403 automobile contact surfaces related to the rider head and neck injuries. The front surfaces and front sides of the cars forward of the front wheel account for 122 or 30.3% of those head and neck injury contacts. The most frequent regions of contact with hard structures were associated with the upper perimeter primary vehicle structures, e.g. headers, rails, and upper pillars. Note the frequency from the following data:

Contact Surface		Frequency
Front	CF09	4
	CF19	8
Side	CS11	34
	CS09	18
	CS15	9
	CS29	18
Back	CB19	9
	CB29	6
TOTAL		106

These 106 contact surfaces (26.3%) represent some of the hardest surfaces on the automobile exterior, in the proximity of the rider's head and neck when collision occurs. The roof rail (CS11) is the most frequent surface contacted.

Table 8.7.5c shows the rider head and neck injury contact surfaces for the pickup, truck, bus and van involvement.

The rider head and neck has injury contact with the undercarriage 7.4% of all head and neck injury contact surfaces.

Table 8.7.5d shows the 721 rider head and neck injury contact surfaces contributed by the environment. The environment provides 55.9% of all the head and neck injury contacts, and pavement (EA01, EC01) and curbs (EC06) provide 76.7% of those impacts. Next in order of the frequency of threat is the combination of trees, poles, posts, barriers, and guardrails (EC02, EC04, EM02, EM04, EM08, EW02) with 15.7% of those head and neck injury surfaces.

Table 8.7.6 (Appendix C.4) shows a cross-tabulation of the contact surface with the body region of the rider head and neck injuries. The application of these data explains the function of the contact surfaces in generating the region injury. A great variety of surfaces participate in a great variety of head and neck regions. The handlebars (MC05) make contact with most areas of the head and neck except the back of the head, the pavement (EA01, EC01) makes injury surface to all exposed areas of the head and neck, and all areas of the vehicles surfaces participate to some degree.

Table 8.7.7 (Appendix C.4) shows the cross-tabulation of the contact surface with the injury severity for the rider head and neck injuries. These data support some very basic concepts about injury mechanisms: (i) hard, rigid surfaces hurt more than soft, yielding surfaces and (ii) the fragile, vulnerable head and neck can be injured by impact with practically any surface. Consider the following examples extracted from Table 8.7.7:

	Contact Surface Injury AIS						
Surface	1	2	3	4	5	6	TOTAL
Concrete Curb EC06	23	7	12	4	10	3	59
Wood Post, Tree EW02	13	3	3	1	4	2	26
Side Door CS06	15	1	1	1	1	1	20
Rear Side Fender CS14	13	3	2	0	1	0	19

The first two surfaces are hard and unyielding and the injuries with AIS ≥ 3 are typically 40 to 50% of the total. The second two surfaces are relatively soft and flexible and the injuries are typically 15 to 20% of the total. In this way, the hard surfaces are overrepresented and the soft surfaces are underrepresented but all surfaces participate easily in severe injury to the vulnerable head and neck.

8.8 Injury Association

The measure of injury severity is selected as the sum of the squares of the Abbreviated Injury Scores for the individual injuries. This does not employ the Injury Severity Score (ISS) as defined in the AIS-80, and will be referred to as the Severities Sum (SS). It is assumed here that the greater detail available for the individual injuries, and the standardization of injury description for the injuries of high severity, will provide a greater distinction for those factors which are associated with injury causation.

In these data, the Somatic Severities Sum (SS1) is combined with the Head and Neck severities sum (SS2) to provide the overall Severities Sum (SS = SS1 + SS2).

The status of the motorcycle rider injuries is summarized in Table 8.8.1, for the 900 on-scene, in-depth accident cases. These generalized descriptions of injury status are crosstabulated with Severities Sum (SS) in Table 8.8.2 (Appendix C.4). The critical parts of this crosstabulation are as follows:

Rider Treatment	Median SS
1. First Aid At Scene	2.62
2. Treated, Released	4.50
3. Hospitalized, 24 Hours	6.51
4. Hospitalized, Significant Rx	15.62
5. Outpatient Care	2.32
6, 7, 8, 9. All Fatals	105.0

TABLE 8.8.1. STATUS OF RIDER TRAUMATIC INJURIES (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
First Aid-Scene	1.	80	8.9	10.1
Treated, Released	2.	328	36.4	41.6
Hospitalized - 24 Hours	3.	29	3.2	3.7
Hospitalized-Significant R_x	4.	219	24.3	27.8
Outpatient Care	5.	79	8.8	10.0
Dead On Scene	6.	31	3.4	3.9
Dead on Arrival	7.	10	1.1	1.3
Fatal within 24 Hours	8.	9	1.0	1.1
Other Fatal	9.	4	0.4	0.5
Unknown	98.	4	0.4	Missing
N.A.	99.	107	11.9	Missing
	TOTAL	900	100.0	100.0

In these data, "First Aid At The Scene," and "Outpatient Care" are essentially equivalent treatment and are so reflected with approximately the same median SS, which corresponds to minor injury status. "Treatment and Released" has a higher median SS, but corresponding to the moderate injury status. "Hospitalized For Less Than 24 Hours" has even higher median SS which barely corresponds to the severe injury status. "Hospitalized For Significant Treatment" has the yet higher median SS of 15.62, which corresponds to the serious injury status.

If only one single fatal injury were incurred (AIS:6) the corresponding SS would be 36. The lowest fatal SS in these data was 46, and the case involved dominant head injury to an unhelmeted rider. At the 10% level the fatal SS was 58, and the median (50%) was 105.

The median non-fatal SS was 4.67, and a comparison of fatal and non-fatal SS is shown in Table 8.8.3 (Appendix C.4).

Table 8.8.4 shows a tabulation of the motorcycle crash speeds for the 900 on-scene, in-depth accident cases. Recall from Section 6.8 that for these accident data the median pre-crash speed is 29.8 mph and the median crash speed is 21.5 mph. Table 8.8.5 (Appendix C.4) crosstabulates these motorcycle crash speeds with overall severities sum (SS) for the motorcycle rider.

TABLE 8.8.4. MOTORCYCLE CRASH SPEED SUMMARY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Speed, mph					
1-10	1.	83	9.2	9.2	9.2
11-20	2.	349	38.8	38.8	48.1
21-30	3.	270	30.0	30.0	78.1
31-40	4.	129	14.3	14.3	92.4
41-50	5.	32	3.6	3.6	96.0
51-60	6.	24	2.7	2.7	98.7
61-70	7.	9	1.0	1.0	99.7
71-80	8.	2	0.2	0.2	99.9
N.A.	99.	1	0.1	0.1	100.0
Unknown	98.	1	0.1	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 8.8.6 shows a summary of crash speed and grouped Severities Sums (SS). The groups are taken as essentially equivalent to the related overall Abbreviated Injury Scores, e.g., the range of SS from 6 through 12 relates to an overall AIS of approximately 3, or "severe" injury. These summarized data show that crash speed is a critical factor relating to injury severity at all levels of injury, and a simplified examination of these various injury levels is shown in Table 8.8.7.

TABLE 8.8.6. SUMMARY OF INJURY SEVERITIES SUM (SS) BY CRASH SPEED

SS	Count Row Pct	Crash Speed, mph 0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	Unknown	Total Col Pct
0-2 (Minor)		33 18.8	90 51.2	35 19.9	15 8.5	1 0.6	0 0.0	1 0.6	0 0.0	1 0.6	176 19.6
3-5 (Moderate)		26 9.7	136 50.9	69 25.8	22 8.2	5 1.8	7 2.6	1 0.4	0 0.0	1 0.4	267 29.7
6-12 (Severe)		17 7.0	88 36.1	93 38.1	31 12.7	8 3.3	6 2.4	1 0.4	0 0.0	0 0.0	244 27.1
13-20 (Serious)		4 5.1	16 20.5	34 43.6	16 20.5	4 5.1	1 1.3	2 2.6	1 1.3	0 0.0	78 8.7
21-30 (Critical)		2 4.4	5 10.9	20 43.5	12 26.1	5 10.9	1 2.2	0 0.0	1 2.2	0 0.0	46 5.1
31-42 (Fatal)		0 0.0	3 14.3	8 38.1	8 38.1	1 4.8	1 4.8	0 0.0	0 0.0	0 0.0	21 2.3
43+ (Fatal plus)		1 1.5	11 16.2	11 16.2	25 36.8	8 11.8	8 11.8	4 5.9	0 0.0	0 0.0	68 7.6
TOTAL ROW PCT		83 9.2	349 38.8	270 30.0	129 14.3	32 3.6	24 2.7	9 1.0	2 0.2	2 0.2	900 100.0

Table 8.8.8 shows a tabulation of the motorcycle rider alcohol and drug involvement for the 900 on-scene, in-depth accident cases. As shown here, there was a confirmed involvement of alcohol and/or drugs for 11.8% of the motorcycle riders. To be sure, there was suspicion of alcohol and drug involvement in some other cases, but only the data shown were confirmed by investigation. Table 8.8.9 (Appendix C.4) crosstabulates these motorcycle rider alcohol and/or drug involvements with overall Severities Sum (SS) for the motorcycle rider.

Table 8.8.10 shows a summary of alcohol and/or drug involvement and grouped Severities Sum (SS). The groups are taken as essentially equivalent to the related overall Abbreviated Injury Scores, e.g., the range of SS from 31 through 42 relates to an overall AIS of approximately 6, or "fatal" injury and scores greater than 43 related extreme injury. These summarized data show that alcohol/drug involvement is a critical factor relating to injury severity at all levels, especially the fatal accident injury levels (SS≥30). Table 8.8.11 illustrates these factors with simplified examination at various injury levels.

Table 8.8.12 shows a summary of motorcycle engine displacement for the 900 on-scene, in-depth accident cases. The motorcycles are grouped in engine displacement as follows:

Motorcycle Size	Description
0-100cc	Small Motorcycles, Mini-bikes and Mopeds
101-250cc	Lightweight Motorcycles
251-500cc	Medium Motorcycles
501-750cc	Large Motorcycles
Over 750cc	Heavyweight Motorcycles

TABLE 8.8.7. INJURY SEVERITY BY CRASH SPEED

(a)

SS	Crash Speed 0-30 mph	30+ mph	Total
0-5	389	52	441
6+	313	144	457
TOTAL	702	196	898
	(χ^2 = 49.99)		

(b)

SS	Crash Speed 0-30 mph	30+ mph	Total
0-12	587	98	685
13+	115	98	213
TOTAL	702	196	898
	(χ^2 = 93.86)		

(c)

SS	Crash Speed 0-30 mph	30+ mph	Total
0-20	641	122	763
21+	61	74	135
TOTAL	702	196	898
	(χ^2 = 101.34)		

(d)

SS	Crash Speed 0-30 mph	30+ mph	Total
0-30	688	141	809
31+	34	55	89
TOTAL	702	196	898
	(χ^2 = 89.93)		

(e)

SS	Crash Speed 0-30 mph	30+ mph	Total
0-42	679	151	830
43+	23	45	68
TOTAL	702	196	898
	(χ^2 = 82.02)		

TABLE 8.8.8. SUMMARY OF RIDER ALCOHOL AND DRUG INVOLVEMENT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
HBD, Not Under Influence	1.	35	3.9	4.0	4.0
HBD, Under Influence	2.	37	4.1	4.2	8.2
HBD, Impairment Unknown	3.	23	2.6	2.6	10.8
Drug Influence	4.	3	0.3	0.3	11.2
Combination	5.	5	0.6	0.6	11.8
N.A.	9.	773	85.9	88.2	100.0
Unknown	8.	24	2.7	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 8.8.10. SS AND ALCOHOL/DRUG INVOLVEMENT SUMMARY

	Rider Alcohol or Drug Involvement							
	Had Been Drinking			Drug Influence	Combi-nation	Unknown	None	Total
SS	NUI	DUI	Unknown					
0-2 (Minor)	4	9	2	0	0	5	156	176
3-5 (Moderate)	11	8	4	1	0	5	238	267
6-12 (Severe)	7	5	5	0	3	5	219	244
13-20 (Serious)	4	1	4	0	0	3	66	78
21-30 (Critical)	2	1	4	0	0	1	38	46
31-42 (Fatal)	0	0	2	0	1	1	17	21
43+ (Fatal +)	7	13	2	2	1	4	39	68
TOTAL	35	37	23	3	5	24	773	900

NOTE: NUI: Not Under Influence, .00% < BAC < .10%
DUI: Driving Under Influence, BAC $\geq$ .10%

TABLE 8.8.11. INJURY SEVERITY AND ALCOHOL/DRUG INVOLVEMENT

(a)

SS	Involvement None	Involvement HBD+	Total
0-5	394	39	433
6+	379	64	443
TOTAL	773	103	876
	(χ^2 = 5.73)		

(b)

SS	Involvement None	Involvement HBD+	Total
0-12	613	59	672
13+	160	44	204
TOTAL	773	103	876
	(χ^2 = 23.45)		

(c)

SS	Involvement None	Involvement HBD+	Total
0-20	679	68	747
21+	94	35	129
TOTAL	773	103	876
	(χ^2 = 32.75)		

(d)

SS	Involvement None	Involvement HBD+	Total
0-30	717	75	792
31+	56	28	84
TOTAL	773	103	876
	(χ^2 = 39.42)		

(e)

SS	Involvement None	Involvement HBD+	Total
0-42	734	78	812
43+	39	25	64
TOTAL	773	103	876
	(χ^2 = 46.81)		

TABLE 8.8.12. MOTORCYCLE ENGINE DISPLACEMENT SUMMARY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Engine Displacement, cc.					
0-100	1.	83	9.2	9.2	9.2
101-250	2.	120	13.3	13.3	22.6
251-500	3.	327	36.3	36.3	58.9
501-750	4.	228	25.3	25.3	84.2
750+	5.	141	15.7	15.7	99.9
Unknown	8.	1	0.1	0.1	100.0
	TOTAL	900	100.0	100.0	

Table 8.8.13 (Appendix C.4) shows a crosstabulation of motorcycle engine displacement and overall severities sum (SS) for the motorcycle riders. Table 8.8.14 shows a summary of motorcycle size and grouped severities sum (SS). The SS groups are taken as essentially equivalent to the related overall AIS. These summarized data show that the large motorcycles (>500 cc) are overrepresented in the higher levels of injury severity, and a significant plateau occurs in the approximate region of SS = 12. Large and heavyweight motorcycles are significantly overrepresented above this plateau, i.e., serious and critical injuries. Table 8.8.15 illustrates these factors with simplified examination at various injury levels.

TABLE 8.8.14. SUMMARY OF SEVERITIES SUM (SS) BY MOTORCYCLE ENGINE DISPLACEMENT

SS / Count / Row Pct	Engine Displacement, cc. 0-100	101-250	251-500	501-750	751+	Unknown	Total Col Pct
0-2 (Minor)	20 11.4	21 11.9	59 33.5	49 27.8	27 15.3	0 0.0	176 19.6
3-5 (Moderate)	22 8.2	46 17.2	102 38.2	61 22.8	36 13.5	0 0.0	267 29.7
6-12 (Severe)	27 11.1	34 13.9	94 38.5	55 22.5	34 13.9	0 0.0	244 27.1
13-20 (Serious)	5 6.4	9 11.5	23 29.5	24 30.8	17 21.8	0 0.0	78 8.7
21-30 (Critical)	4 8.7	2 4.3	18 39.1	9 19.6	12 26.1	1 2.2	46 5.1
31-42 (Fatal)	1 4.8	1 4.8	7 33.3	9 42.9	3 14.3	0 0.0	21 2.3
43+ (Fatal Plus)	4 5.9	7 10.3	24 35.3	21 29.4	12 17.6	0 0.0	68 7.6
Total Row Pct	83 9.2	120 13.3	327 36.3	228 25.3	141 15.7	1 0.1	900 100.0

TABLE 8.8.15. SS AND MOTORCYCLE SIZE

(a)

SS	Motorcycle Size 0-500 cc	501+ cc	Total
0-5	270	173	443
6+	260	196	456
TOTAL	530	369	899
	(χ^2 = 1.28)		

(b)

SS	Motorcycle Size 0-500 cc	501+ cc	Total
0-12	425	262	687
13+	105	107	212
TOTAL	530	369	899
	(χ^2 = 9.68)		

(c)

SS	Motorcycle Size 0-500 cc	501+ cc	Total
0-20	462	303	765
21+	68	66	134
TOTAL	530	369	899
	(χ^2 = 3.99)		

(d)

SS	Motorcycle Size 0-500 cc	501+ cc	Total
0-30	486	324	810
31+	44	45	89
TOTAL	530	369	899
	(χ^2 = 3.27)		

(e)

SS	Motorcycle Size 0-500 cc	501+ cc	Total
0-42	495	336	831
43+	35	33	68
TOTAL	530	369	899
	(χ^2 = 1.38)		

8.9 Groin Injuries

Early in the course of data collection, it became apparent that a substantial number of riders (and some passengers) complained of injury to the groin and often diffuse abdominal pain. In most instances this was associated with a characteristic pattern of damage to the motorcycle in which the top and sides at the back of the fuel tank was deformed inwards. Indeed, it was often possible to tell the type of cloth of the rider's pants (such as corduroy) from the cloth marks left on the paint. Handlebars typically showed signs of rider contact such as bending or forward rotation in the clamps.

A total of 117 riders sustained groin injuries (13% of the 900 cases) which ranged from simple complaints of pain to rupture of the urinary and severe lacerations of the penis. Basic information defining the injury is shown in Table 8.9.1, which shows the distribution of lesion type and the system or organ involved. The large majority of groin injuries involved no external bleeding; contusion of the genitals accounted for 87.2% of the groin injuries. The lack of external trauma often led treating physicans to overlook the groin injury. Many of the riders were hospitalized for testing for internal injuries (testing was usually negative) when they were simply suffering referred pain from groin impact.

TABLE 8.9.1. GROIN INJURY LESION TYPE AND SYSTEM/ORGAN INVOLVED

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Lesion Type				
Contusion	C	102	87.2	87.2
Laceration	L	12	10.3	10.3
Pain	P	1	0.9	0.9
Rupture	R	1	0.9	0.9
Avulsion	V	1	0.9	0.9
	TOTAL	117	100.0	100.0
System/Organ				
Urogenital	G	115	98.3	99.1
Integument	I	1	0.9	0.9
Unknown	U	1	0.9	Missing
	TOTAL	117	100.0	100.0

The distribution of groin injury severity is shown in Table 8.9.2. The majority of groin injuries were of a minor nature, at least as far as AIS scores are concerned. The severe and serious injuries demonstrated injury not only to the external genitalia, but involved pelvic and perineal structures as well, e.g., pelvic fractures and ruptures of the urinary bladder.

TABLE 8.9.2. GROIN INJURY SEVERITY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Minor	1.	92	78.6	78.6	78.6
Moderate	2.	17	14.5	14.5	93.2
Severe	3.	6	5.1	5.1	98.3
Serious	4.	2	1.7	1.7	100.0
	TOTAL	117	100.0	100.0	

Collision Characteristics

The impact region on the motorcycle was defined for those accidents in which the rider sustained groin injuries. The distribution of impact regions is shown in Table 8.9.3. Two-thirds of the groin injury accidents were direct frontal collisions; frontal and angular-frontal (F + RF + LF) collisions totalled 89.7% of the groin injury accidents.

TABLE 8.9.3 COLLISION CONTACT LOCATION ON MOTORCYCLE GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Left Center	LC	6	5.1	5.1
Left Front	LF	16	13.7	13.7
Right Back	RB	1	0.9	0.9
Right Center	RC	3	2.6	2.6
Right Front	RF	11	9.4	9.4
Back	OB	2	1.7	1.7
Front	OF	78	66.7	66.7
	TOTAL	117	100.0	100.0

While 74.1% of the 900 accidents were multiple-vehicle collisions, an unusually high proportion (91.5%) of the groin injury accidents involved another vehicle, as shown in Table 8.9.4.

TABLE 8.9.4. SINGLE OR MULTIPLE VEHICLE COLLISION GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Single Vehicle Collision	1.	10	8.5	8.5
Multi-Vehicle Collision	2.	107	91.5	91.5
	TOTAL	117	100.0	100.0

The distribution of crash speeds in groin injury accidents is shown in Table 8.9.5. The median speed shown in the table is 26.7 mph. This is substantially higher than the median crash speed of the 900 OSID cases, which was 21.5 mph.

TABLE 8.9.5. MOTORCYCLE CRASH SPEED IN GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Speed, mph					
0-10	1.	3	2.6	2.6	2.6
11-20	2.	25	21.4	21.4	23.9
21-30	3.	45	38.5	38.5	62.4
31-40	4.	36	30.8	30.8	93.2
41-50	5.	5	4.3	4.3	97.4
51-60	6.	2	1.7	1.7	99.1
61-70	7.	1	0.9	0.9	100.0
	TOTAL	117	100.0	100.0	

The object(s) impacting the rider's groin region were defined for each accident. As can be seen in Table 8.9.6, the fuel tank is the predominating contact surface; of 117 riders suffering groin injury, 103 (88%) made contact with the fuel tank while 48.7% impacted the handlebars. The pattern of damage to the fuel tank was so typical that one could virtually predict the presence of groin injury on the basis of tank deformation.

TABLE 8.9.6. GROIN INJURY CONTACT SURFACES

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Car Bumper	CF01	1	0.5	0.5	0.5
Headlamp, Front Corner	CF03	1	0.5	0.5	1.0
Front Fender	CS02	1	0.5	0.5	1.5
Front Door	CS06	1	0.5	0.5	2.0
Rear Door	CS12	1	0.5	0.5	2.6
Rear Fender	CS14	1	0.5	0.5	3.1
Asphalt Pavement	EA01	2	1.0	1.0	4.1
Concrete Pavement	EC01	1	0.5	0.5	4.6
Flat Soil	ES13	1	0.5	0.5	5.1
Tree, Wooden Pole	EW02	1	0.5	0.5	5.6
Tank Cap	MC01	2	1.0	1.0	6.6
Fuel Tank	MC02	103	52.6	52.6	59.2
Steering Head Assembly	MC03	8	4.1	4.1	63.3
Handlebars	MC05	57	29.1	29.1	92.3
Instruments	MC06	8	4.1	4.1	96.4
Windshield	MC07	1	0.5	0.5	96.9
Front Forks, Suspension	MC08	2	1.0	1.0	98.0
Fairing	MC17	2	1.0	1.0	99.0
Other Motorcycle Parts	MC97	2	1.0	1.0	100.0
	TOTAL	196	100.0	100.0	

The very high incidence of fuel tank involvement in groin injuries does not mean that the fuel tank is the grim destroyer of rider groin regions. In general, there is no more benign surface on the motorcycle; the fuel tank deforms readily under loading and thus tends to reduce the severity of injury relative to other surfaces on the motorcycle. The high level of fuel tank and handlebar involvement simply reflects the fact that 91.5% of the groin injury accidents are frontal or angular-frontal collisions and that--as elementary physics suggests--the rider tends to keep moving forward when the motorcycle stops, coming into contact with the objects immediately in front of him.

Motorcycle Characteristics

The manufacturers of motorcycles involved in groin injury accidents are shown in Table 8.9.7. The last column of numbers in the table shows the adjusted frequency of overall accident involvement for the same manufacturers in the 900 on-scene, in-depth investigations.

The displacements of motorcycles involved in groin injury accidents are shown in Table 8.9.8. The median displacement in the table is 480cc. This is somewhat higher than the 420cc median for the 900 OSID cases, but considerably less than the 650cc median for the 54 fatal cases.

TABLE 8.9.7. MOTORCYCLE MANUFACTURERS, GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	OSID Adj. Frequency (%)
BMW	3.	3	2.6	1.6
BSA	4.	2	1.7	0.9
Ducati	14.	1	0.9	0.2
Harley-Davidson	20.	18	15.4	10.6
Honda	23.	59	50.4	55.7
Kawasaki	28.	6	5.1	8.1
Moto Guzzi	35.	2	1.7	0.8
Norton	40.	3	2.6	0.7
Suzuki	54.	6	5.1	4.4
Triumph	55.	3	2.6	2.0
Vespa	60.	1	0.9	0.8
Yamaha	62.	13	11.1	12.2
	TOTAL	117	100.0	98.0

TABLE 8.9.8. MOTORCYCLE DISPLACEMENT, GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Engine Displacement, cc.					
0 thru 100	1.	6	5.1	5.1	5.1
101 thru 250	2.	14	12.0	12.0	17.1
251 thru 500	3.	42	35.9	35.9	53.0
501 thru 750	4.	33	28.2	28.2	81.2
>750	5.	22	18.8	18.8	100.0
	TOTAL	117	100.0	100.0	

Of the 117 motorcycles involved in rider groin injury accidents, 21 (17.9%) were equipped with crash bars. This percentage is virtually identical to the 18.1% crash bar use in the 900 OSID cases and suggests that crash bars have no effect on groin injuries. This is a factor of importance which relates the uniqueness of motorcycle crash dynamics. The data are shown in Table 8.9.9.

TABLE 8.9.9. CRASH BAR USE IN GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	96	82.1	82.1
Yes	1.	21	17.9	17.9
	TOTAL	117	100.0	100.0

The presence of a passenger behind the rider during a frontal collision might be expected to push the rider's groin more forcefully into the fuel tank and other structures on the forward part of the motorcycle and to increase the incidence of groin injury. Indeed, films of laboratory crash tests conducted by Bothwell suggest that the passenger tends to "ramp" up over the rider during impact. Passengers were involved in 21 of the 117 accidents (17.9%) involving groin injury to the rider. This proportion is not substantially different than the 17.1% passenger involvement in the 900 OSID cases, and suggests that passengers have little to do with the incidence of groin injury in motorcycle accidents. These data are shown in Table 8.9.10.

TABLE 8.9.10. PASSENGER INVOLVEMENT IN RIDER GROIN INJURY ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Number of Passengers	0.	96	82.1
	1.	21	17.9
	TOTAL	117	100.0

Groin Injury Severity Factors

Groin injury severity was cross-tabulated with a number of factors to evaluate those which may affect severity. Collision contact on the motorcycle was thus cross-tabulated with severity and the data are shown in Table 8.9.11. Basically, the table shows no unusual relationship between groin injury severity and the location of impact to the motorcycle. For example, 23 of 25 (92%) groin injuries with AIS-2 or higher occurred in frontal or angular-frontal collisions, which accounted for 87.9% of the groin injury accidents.

The cross-tabulation of groin injury severity with the injury contact surface is shown in Table 8.9.12 (Appendix C.4). Absolute frequencies in the table reflect the severity count by contact surface; since a single groin injury might have two contact surfaces, some groin injuries are counted twice. While fuel tank versus groin impacts accounted for 52.6% of the total groin impact surfaces, the fuel tank accounted for less than its share of AIS-3 and AIS-4 groin injuries, only 26.7%. This is consistent with the suggestion that the deformability and compliance of the fuel tank may contribute to lessening the severity of groin injury.

The relationship between crash speeds and groin injury severity is shown in Table 8.9.13 (Appendix C.4). Generally speaking, the severity of groin injury tends to increase as speeds increase. For example, the median speed at each severity level is as follows: AIS-1: 26.1 mph, AIS-2: 28.6 mph, AIS-3: 30.5 mph and AIS-4: 35 mph. Paradoxically, however, seven of the eight groin injury accidents with a crash speed over 40 mph were AIS-1 (minor) severity.

TABLE 8.9.11. MOTORCYCLE COLLISION CONTACT BY GROIN INJURY SEVERITY

Collision Contact	Count Row Pct Col Pct Tot Pct	Groin Injury Severity: Minor	Moderate	Severe	Serious	Row Total
Left Center		5 83.3 5.4 4.3	1 16.7 5.9 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 5.1
Left Front		10 62.5 10.9 8.5	5 31.3 29.4 4.3	1 6.3 16.7 0.9	0 0.0 0.0 0.0	16 13.7
Right Back		1 100.0 1.1 0.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.9
Right Center		3 100.0 3.3 2.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 2.6
Right Front		9 81.8 9.8 7.7	1 9.1 5.9 0.9	1 9.1 16.7 0.9	0 0.0 0.0 0.0	11 9.4
Back		1 50.0 1.1 0.9	0 0.0 0.0 0.0	1 50.0 16.7 0.9	0 0.0 0.0 0.0	2 1.7
Front		63 80.8 68.5 53.8	10 12.8 58.8 8.5	3 3.8 50.0 2.6	2 2.6 100.0 1.7	78 66.7
	Column Total	92 78.6	17 14.5	6 5.1	2 1.7	117 100.0

Injury severity was cross-tabulated with motorcycle manufacturer as shown in Table 8.9.14 (Appendix C.4). Honda, Kawasaki, Suzuki and Yamaha accounted for 80.4% of the 900 OSID accidents, 71.7% of the 117 groin injuries and only 52% of the groin injuries with AIS-2 or above. On the other hand, other motorcycles shown in this table accounted for 17.6% of the 900 OSID cases, 28.4% of the groin injuries and 48% of the groin injuries with AIS-2 or more. Honda, Kawasaki, Suzuki and Yamaha motorcycles are under-represented in groin injuries, while other motorcycles (as a group) are overrepresented, and this is statistically significant as shown below.

	AIS = 0	AIS $\geq$ 1	TOTAL
Honda, Kawasaki, Suzuki, Yamaha	640	84	724
All Others	143	33	176
TOTAL	783	117	900

$(\chi^2 = 5.78)$

	AIS = 1	AIS $\geq$ 2	TOTAL
Honda, Kawasaki, Suzuki, Yamaha	71	13	84
All Others	21	12	33
TOTAL	92	25	117

$(\chi^2 = 4.97)$

Engine displacement was cross-tabulated with groin injury severity and the results are shown in Table 8.9.15. The data show that large motorcycles--those over 500cc--accounted for more than their share of serious and severe groin injuries.

Groin injuries rarely present any serious threat to the rider's life, but they have a peculiar poignancy that should not be overlooked. It is also worth noting that the long-term effects of groin injury in motorcycle accidents have not been studied here; serious long-term effects could belie the minor severity currently assigned to most groin injuries, which places them in a category with skinned knees and broken toes.

Bothwell's crash-testing of motorcycles years ago pointed out the necessity for considering rider groin impact in the design of fuel tanks; the suggestion is borne out by the current findings. Rider collision kinematics and human anatomy have not changed since that time and the design of fuel tanks must consider the minimization of groin injuries to the rider.

Any motorcycle rider considering modifications to his motorcycle that will raise the tank, steering head, etc., above seat height--either by installing a new tank, extending the front forks, lowering the seat or some combination of these--should consider that anything he puts in front of his groin region may contribute significant injury.

A final observation is that the groin injury is a signature characteristic of frontal impact on the motorcycle. The unrestrained motorcycle rider is expected to make groin area contact with those motorcycle surfaces immediately ahead of that body region. This situation is similar to the mechanism of chest impact with the steering wheel in automobile collisions. The analogy demands that modern motorcycle design minimize injury and provide smooth energy absorbing surfaces similar to modern automotive steering wheel design.

TABLE 8.9.15. GROIN INJURY SEVERITY BY ENGINE DISPLACEMENT (cc's)

Count Row Pct Col Pct Tot Pct	0-100	101-250	251-500	501-750	750+	Row Total
Minor	4 4.3 66.7 3.4	11 12.0 78.6 9.4	35 38.0 83.3 29.9	27 29.3 81.8 23.1	15 16.3 68.2 12.8	92 78.6
Moderate	1 5.9 16.7 0.9	3 17.6 21.4 2.6	6 35.3 14.3 5.1	4 23.5 12.1 3.4	3 17.6 13.6 2.6	17 14.5
Serious	1 16.7 16.7 0.9	0 0.0 0.0 0.0	1 16.7 2.4 0.9	1 16.7 3.0 0.9	3 50.0 13.6 2.6	6 5.1
Severe	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 3.0 0.9	1 50.0 4.5 0.9	2 1.7
Column Total	6 5.1	14 12.0	42 35.9	33 28.2	22 18.8	117 100.0

9.0 HUMAN FACTORS-PROTECTION SYSTEMS EFFECTIVENESS

Because of the exposed position of the motorcycle rider, accident events provide great opportunity for injury; hence protection is necessary. This section deals with the various protection equipment, appliances and clothing which is available to motorcyclists, and evaluates the effectiveness of those materials in preventing or reducing injury. The accident data are analyzed to answer questions about safety helmet effectiveness, eye protection, leather jackets, heavy boots, etc., as well as distinguish those items which are most effective and which should be used by prudent motorcyclists.

9.1 Protection Systems - General Characteristics

The voluntary use of protection equipment by the motorcycle rider is the prudent thing to do simply because of the high probability of injury in the event of a motorcycle accident. The one item of protective equipment which is unique to the motorcycle is the safety helmet; no other vehicle in traffic use has an associated demand for head protection. Of course, a great quantity of data were collected to describe the use and performance of the safety helmets involved in these accidents, then associate that use with the detailed information on injuries. This sort of analysis can provide an adequate measure of helmet effectiveness in preventing head and neck injury, and then determine the value of safety helmet use as an injury countermeasure.

Table 9.1.1 shows the frequency of injury severity for the most severe injury experienced by the motorcycle riders in the 900 on-scene, in-depth accident cases. Distinction is made for those 900 cases for the motorcycle riders with a safety helmet (355), and those without a safety helmet (537). The population-at-risk shows voluntary helmet use of approximately 50%, and those motorcycle riders involved in these accidents are approximately 40%. The distribution of helmeted and unhelmeted riders throughout the data of Table 9.1.1 at specific injury levels provides interesting but artificial contradictions. When the most severe injury is minor, the distribution according to helmet use is essentially that of the overall distribution, simply because that group is 50.8% of the total. When the most severe injury is moderate, severe and serious, the helmeted riders comprise more than the 40%; but when the most severe injury is critical or fatal, the helmeted riders comprise less than the 40%. This sort of comparison simply defines the contrast and does not specify the benefit or give explanation. Table 9.1.2 provides the equivalent data for the most severe injury for the 152 motorcycle passengers involved in the 900 on-scene, in-depth accident cases.

Table 9.1.3 provides the data for the most severe injury region for the motorcycle riders in the 900 on-scene, in-depth accident cases. As before, the population-at-risk has defined that voluntary helmet use in the study area is approximately 50%, and the helmeted riders are approximately 40% of the accident population. The data of Table 9.1.3 have the potential logical conflict that two or more body regions could have the same highest level of injury severity, so priority is given that the most important of most severe injuries would be ranked in the following order: head, neck, face, chest, abdomen, pelvis and extremities. In this sort of comparison of helmeted and unhelmeted motorcycle riders, any contribution of the helmet use to injury to regions other than the head, face and neck must be

TABLE 9.1.1. FREQUENCY OF INJURY SEVERITY FOR MOST SEVERE INJURY, ALL REGIONS BY HELMET USE (900 MOTORCYCLE RIDERS)

Most Severe Injury	Count / Row Pct / Col Pct / Tot Pct	Helmet Use: With Helmet	Helmet Use: Without Helmet	Helmet Use: Unknown	Row Total
None	Count	4	16	1	21
	Row Pct	19.0	76.2	4.8	2.3
	Col Pct	1.1	3.0	12.5	
	Tot Pct	0.4	1.8	0.1	
Minor	Count	180	274	3	457
	Row Pct	39.4	60.0	0.7	50.8
	Col Pct	50.7	51.0	37.5	
	Tot Pct	20.0	30.4	0.3	
Moderate	Count	84	111	2	197
	Row Pct	42.6	56.3	1.0	21.9
	Col Pct	23.7	20.7	25.0	
	Tot Pct	9.3	12.3	0.2	
Severe	Count	46	58	1	105
	Row Pct	43.8	55.2	1.0	11.7
	Col Pct	13.0	10.8	12.5	
	Tot Pct	5.1	6.4	0.1	
Serious	Count	25	26	0	51
	Row Pct	49.0	51.0	0.0	5.7
	Col Pct	7.0	4.8	0.0	
	Tot Pct	2.8	2.9	0.0	
Critical	Count	7	29	1	37
	Row Pct	18.9	78.4	2.7	4.1
	Col Pct	2.0	5.4	12.5	
	Tot Pct	0.8	3.2	0.1	
Fatal	Count	9	21	0	30
	Row Pct	30.0	70.0	0.0	3.3
	Col Pct	2.5	3.9	0.0	
	Tot Pct	1.0	2.3	0.0	
Unknown	Count	0	2	0	2
	Row Pct	0.0	100.0	0.0	0.2
	Col Pct	0.0	0.4	0.0	
	Tot Pct	0.0	0.2	0.0	
	Column Total	355	537	8	900
		39.4	59.7	0.9	100.0

TABLE 9.1.2. FREQUENCY OF INJURY SEVERITY FOR MOST SEVERE INJURY, ALL REGIONS BY HELMET USE (152 MOTORCYCLE PASSENGERS)

Most Severe Injury	Count Row Pct Col Pct Tot Pct	Helmet Use: With Helmet	Helmet Use: Without Helmet	Helmet Use: Unknown	Row Total
None		2 40.0 8.3 1.3	2 40.0 1.6 1.3	1 20.0 100.0 0.7	5 3.3
Minor		16 17.0 66.7 10.5	78 83.0 61.4 51.3	0 0.0 0.0 0.0	94 61.8
Moderate		4 16.7 16.7 2.6	20 83.3 15.7 13.2	0 0.0 0.0 0.0	24 15.8
Severe		2 11.8 8.3 1.3	15 88.2 11.8 9.9	0 0.0 0.0 0.0	17 11.2
Serious		0 0.0 0.0 0.0	4 100.0 3.1 2.6	0 0.0 0.0 0.0	4 2.6
Critical		0 0.0 0.0 0.0	7 100.0 5.5 4.6	0 0.0 0.0 0.0	7 4.6
Fatal		0 0.0 0.0 0.0	1 100.0 0.8 0.7	0 0.0 0.0 0.0	1 0.7
	Column Total	24 15.8	127 83.6	1 0.7	152 100.0

TABLE 9.1.3. REGION OF MOST SEVERE INJURY BY HELMET USE (900 MOTORCYCLE RIDERS)

Region	Count / Row Pct / Col Pct / Tot Pct	With Helmet	Without Helmet	Unknown	Row Total
No Injury	Count	4	16	1	21
	Row Pct	19.0	76.2	4.8	2.3
	Col Pct	1.1	3.0	12.5	
	Tot Pct	0.4	1.8	0.1	
Extremities	Count	207	207	5	419
	Row Pct	49.4	49.4	1.2	46.6
	Col Pct	58.3	38.5	62.5	
	Tot Pct	23.0	23.0	0.6	
Pelvis	Count	28	33	1	62
	Row Pct	45.2	53.2	1.6	6.9
	Col Pct	7.9	6.1	12.5	
	Tot Pct	3.1	3.7	0.1	
Abdomen	Count	23	25	0	48
	Row Pct	47.9	52.1	0.0	5.3
	Col Pct	6.5	4.7	0.0	
	Tot Pct	2.6	2.8	0.0	
Chest	Count	40	56	1	97
	Row Pct	41.2	57.7	1.0	10.8
	Col Pct	11.3	10.4	12.5	
	Tot Pct	4.4	6.2	0.1	
Face	Count	18	35	0	53
	Row Pct	34.0	66.0	0.0	5.9
	Col Pct	5.1	6.5	0.0	
	Tot Pct	2.0	3.9	0.0	
Neck	Count	11	19	0	30
	Row Pct	36.7	63.3	0.0	3.3
	Col Pct	3.1	3.5	0.0	
	Tot Pct	1.2	2.1	0.0	
Head	Count	23	145	0	168
	Row Pct	13.7	86.3	0.0	18.7
	Col Pct	6.5	27.0	0.0	
	Tot Pct	2.6	16.1	0.0	
Unknown	Count	0	1	0	1
	Row Pct	0.0	100.0	0.0	0.1
	Col Pct	0.0	0.2	0.0	
	Tot Pct	0.0	0.1	0.0	
Whole Body	Count	1	0	0	1
	Row Pct	100.0	0.0	0.0	0.1
	Col Pct	0.3	0.0	0.0	
	Tot Pct	0.1	0.0	0.0	
	Column Total	355	537	8	900
		39.4	59.7	0.9	100.0

evaluated carefully. The major factor shown by the data of Table 9.1.3 is that safety helmet use is clearly associated with reduced head, neck and face injuries.

Table 9.1.4 shows the same type of data for the region of most severe injuries to the 900 motorcycle riders, but all highest injury severity duplicates are counted. Note the much larger count for the extremities injuries where it would be typical for the accident-involved motorcycle rider to experience abrasion, contusion and laceration in many areas of the extremities and each injury has AIS = 1. Also, note that the distribution of injuries counted for helmeted and unhelmeted riders now appears essentially the same as the accident population. When the effect of helmet use is examined for the counted most severe head, neck and face injuries, the same approximate advantage is shown for helmeted riders having less head injuries, and less neck and face injuries.

Table 9.1.5 shows the data equivalent to that of Table 9.1.3, with the most severe injury region for the 152 passengers in the on-scene, in-depth accident cases. In the cases of duplicate most severe injuries, only one is counted with the priority of head, neck, face, chest, abdomen, pelvis and extremities. Because of the numerical requirements for significant distributions, these data are useful only to show the distribution of those most severe injuries to the body regions for both helmeted and unhelmeted passengers. The only important distinction for helmet use available from this comparison is that helmeted passengers have notably fewer cases of head injury.

The data of Tables 9.1.3 and 9.1.5 demonstrate the need for more specific separation of the factors associated with injury to the riders and passengers so that specific effects of protective equipment can be evaluated.

Table 9.1.6 shows the distribution of helmeted and unhelmeted motorcycle riders and passengers in the 900 on-scene, in-depth accident cases who suffered FATAL injuries. These 59 fatalities clearly demonstrate a general advantage for the use of the safety helmet: helmeted riders were 50% of the population-at-risk, 40% of the accident population, but only 20% of the fatal cases! Since the data are presented for FATAL cases only, the distinction of helmet use is not significant. The purpose is to show that a characteristic of fatally injured motorcycle riders and passengers is that approximately 60% have critical or fatal head injuries.

Further analysis within this section will expose the specific factors of various items of protective equipment.

9.2 Eye Protection

Table 9.2.1 shows the eye protection worn by the riders in the 900 accident cases; 73.2% of those riders had no eye protection at all! The predominating eye protection equipment (18.1%) was the wrap-around face shield which, of course, was a helmet appliance. The wrap-around face shield generally has only one curvature and has no significant optical quality problems. The bubbleshield, which has double curvature and the accompanying low optical quality, was 4.7% of the eye protection worn.

TABLE 9.1.4. REGION OF MOST SEVERE INJURIES
BY HELMET USE
(900 MOTORCYCLE RIDERS)
HIGHEST INJURY SEVERITY DUPLICATES COUNTED

Region	Count Row Pct Col Pct Tot Pct	With Helmet	Without Helmet	Unknown	Row Total
No Injury		4 19.0 0.5 0.2	16 76.2 1.2 0.7	1 4.8 7.1 0.0	21 1.0
Extremities		573 41.2 72.8 26.8	808 58.0 60.3 37.8	11 0.8 78.6 0.5	1392 65.0
Pelvis		42 38.5 5.3 2.0	66 60.6 4.9 3.1	1 0.9 7.1 0.0	109 5.1
Abdomen		37 41.1 4.7 1.7	53 58.9 4.0 2.5	0 0.0 0.0 0.0	90 4.2
Chest		65 40.4 8.3 3.0	95 59.0 7.1 4.4	1 0.6 7.1 0.0	161 7.5
Face		28 22.6 3.6 1.3	96 77.4 7.2 4.5	0 0.0 0.0 0.0	124 5.8
Neck		12 26.1 1.5 0.6	34 73.9 2.5 1.6	0 0.0 0.0 0.0	46 2.1
Head		24 12.6 3.0 1.1	167 87.4 12.5 7.8	0 0.0 0.0 0.0	191 8.9
Unknown		0 0.0 0.0 0.0	4 100.0 0.3 0.2	0 0.0 0.0 0.0	4 0.2
Whole Body		2 100.0 0.3 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.1
	Column Total	787 36.8	1339 62.6	4 0.7	2140 100.0

TABLE 9.1.5. REGION OF MOST SEVERE INJURY BY HELMET USE (152 MOTORCYCLE PASSENGERS)

Region	Count Row Pct Col Pct Tot Pct	With Helmet	Without Helmet	Unknown	Row Total
No Injury		2 40.0 8.3 1.3	2 40.0 1.6 1.3	1 20.0 100.0 0.7	5 3.3
Extremities		11 18.3 45.8 7.2	49 81.7 38.6 32.2	0 0.0 0.0 0.0	60 39.5
Pelvis		1 12.5 4.2 0.7	7 87.5 5.5 4.6	0 0.0 0.0 0.0	8 5.3
Abdomen		1 25.0 4.2 0.7	3 75.0 2.4 2.0	0 0.0 0.0 0.0	4 2.6
Chest		4 16.0 16.7 2.6	21 84.0 16.5 13.8	0 0.0 0.0 0.0	25 16.4
Face		1 10.0 4.2 0.7	9 90.0 7.1 5.9	0 0.0 0.0 0.0	10 6.6
Neck		1 14.3 4.2 0.7	6 85.7 4.7 3.9	0 0.0 0.0 0.0	7 4.6
Head		3 9.4 12.5 2.0	29 90.6 22.8 19.1	0 0.0 0.0 0.0	32 21.1
Whole Body		0 0.0 0.0 0.0	1 100.0 0.8 0.7	0 0.0 0.0 0.0	1 0.7
	Column Total	24 15.8	127 83.6	1 0.7	152 100.0

TABLE 9.1.6. MOTORCYCLE RIDERS AND PASSENGERS FATALLY INJURED WITH CRITICAL OR FATAL HEAD INJURIES

Helmet Use / Count / Row Pct / Col Pct / Tot Pct	Head Injuries - AIS = 5 or 6		Row Total
	Yes	No	
With Helmet	7 58.3 20.6 11.9	5 41.7 20.0 8.5	12 20.3
Without Helmet	27 58.7 79.4 45.8	19 41.3 76.0 32.2	46 78.0
Unknown	0 0.0 0.0 0.0	1 100.0 4.0 1.7	1 1.7
Column Total	34 57.6	25 42.4	59 100.0

(54 riders; 5 passengers)

TABLE 9.2.1. MOTORCYCLE RIDER EYE PROTECTION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	595	66.1	73.2
Goggles	1.	28	3.1	3.4
Wrap Shield	2.	114	12.7	14.0
Bubble Shield	3.	38	4.2	4.7
Visor and Shield	4.	33	3.7	4.1
Other	5.	5	0.6	0.6
Unknown	8.	49	5.4	Missing
N.A.	9.	38	4.2	Missing
	TOTAL	900	100.0	100.0

Table 9.2.2 shows the color of the eye protection worn by the motorcycle riders in the 900 accident cases. The color was noted so that evaluation could be made to determine if shading would affect hazard detection in low light conditions.

Table 9.2.3 shows the type of glasses worn by the motorcycle riders in the 900 accident cases. Eye glass use data was collected independent of eye protection (Table 9.2.1). Non-prescription sunglasses were the most commonly used (17.1%).

TABLE 9.2.2. MOTORCYCLE RIDER EYE PROTECTION COLOR (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Clear	1.	140	15.6	63.3
Green	2.	4	0.4	1.8
Amber	3.	27	3.0	12.3
Smoke	4.	38	4.2	17.3
Blue	5.	8	0.9	3.6
Other	6.	3	0.3	1.4
Unknown	8.	42	4.7	Missing
N.A.	9.	638	70.9	Missing
	TOTAL	900	100.0	100.0

TABLE 9.2.3. MOTORCYCLE RIDER EYEGLASSES WORN (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	521	57.9	64.5
Prescription Glasses	1.	114	12.7	14.1
Contact Lenses	2.	11	1.2	1.4
Prescription Sunglasses	3.	21	2.3	2.6
Contacts and Sunglasses	4.	1	0.1	0.1
Non-Prescription Sunglasses	5.	138	15.3	17.1
Non-Prescription Clear Glass	6.	2	0.2	0.2
Unknown	8.	79	8.8	Missing
N.A.	9.	13	1.4	Missing
	TOTAL	900	100.0	100.0

Prescription glasses, sunglasses and contact lenses were encountered with 18.2% of the accident-involved riders, and 6.0% of the riders required but did not wear corrective lenses at the time of the accident.

The lack of eye protection has some serious implications for accident involvement. If the motorcycle rider has no eye protection, the wind blast onto the bare eyes can cause tearing, squinting, blinking, accommodation, etc., and an overall impairment of vision which could delay hazard detection and degrade collision avoidance performance.

Table 9.2.4 provides a crosstabulation of motorcycle eye protection and eyeglass use for the 900 on-scene, in-depth accident cases. The outstanding feature of these data is that 39.8% of the accident-involved riders had neither eye protection nor eyeglasses. This group of motorcycle riders has been isolated for analysis and Tables 9.2.5, 6 and 7 show the collision avoidance performance of these 358 accident-involved motorcycle riders. This group without eye protection or eyeglasses is shown to perform just as badly as the other accident-involved riders but with inferior execution and choice of evasive action. Also, Table 9.2.8

TABLE 9.2.4. RIDER EYE PROTECTION WORN BY TYPE OF GLASSES WORN BY RIDER (OSIDs)

Count / Row Pct / Col Pct / Tot Pct	None	Pre-scrip. Glasses	Con-tact Lenses	Pre-scrip. Sun-glasses	Con-tacts and Sun-glasses	Non-Pre. Sun-glasses	Non-Pre. Clear Glasses	Unknown	N.A.	Row Total
None	358	61	6	17	1	114	2	33	3	595
	60.2	10.3	1.0	2.9	0.2	19.2	0.3	5.5	0.5	66.1
	68.7	53.5	54.5	81.0	100.0	82.6	100.0	41.8	23.1	
	39.8	6.8	0.7	1.9	0.1	12.7	0.2	3.7	0.3	
Goggles	24	4	0	0	0	0	0	0	0	28
	85.7	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1
	4.6	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	2.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Wrap Shield	76	23	3	4	0	7	0	1	0	114
	66.7	20.2	2.6	3.5	0.0	6.1	0.0	0.9	0.0	12.7
	14.6	20.2	27.3	19.0	0.0	5.1	0.0	1.3	0.0	
	8.4	2.6	0.3	0.4	0.0	0.8	0.0	0.1	0.0	
Bubble Shield	27	6	1	0	0	4	0	0	0	38
	71.1	15.8	2.6	0.0	0.0	10.5	0.0	0.0	0.0	4.2
	5.2	5.3	9.1	0.0	0.0	2.9	0.0	0.0	0.0	
	3.0	0.7	0.1	0.0	0.0	0.4	0.0	0.0	0.0	
Visor and Shield	21	5	1	0	0	6	0	0	0	33
	63.6	15.2	3.0	0.0	0.0	18.2	0.0	0.0	0.0	3.7
	4.0	4.4	9.1	0.0	0.0	4.3	0.0	0.0	0.0	
	2.3	0.6	0.1	0.0	0.0	0.7	0.0	0.0	0.0	
Other	2	1	0	0	0	2	0	0	0	5
	40.0	20.0	0.0	0.0	0.0	40.0	0.0	0.0	0.0	0.6
	0.4	0.9	0.0	0.0	0.0	1.4	0.0	0.0	0.0	
	0.2	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	
Unknown	3	5	0	0	0	0	0	41	0	49
	6.1	10.2	0.0	0.0	0.0	0.0	0.0	83.7	0.0	5.4
	0.6	4.4	0.0	0.0	0.0	0.0	0.0	51.9	0.0	
	0.3	0.6	0.0	0.0	0.0	0.0	0.0	4.6	0.0	
N.A.	10	9	0	0	0	5	0	4	10	38
	26.3	23.7	0.0	0.0	0.0	13.2	0.0	10.5	26.3	4.2
	1.9	7.9	0.0	0.0	0.0	3.6	0.0	5.1	76.9	
	1.1	1.0	0.0	0.0	0.0	0.6	0.0	0.4	1.1	
Column Total	521	114	11	21	1	138	2	79	13	900
	57.9	12.7	1.2	2.3	0.1	15.3	0.2	8.8	1.4	100.0

shows that this group without eye protection had their attention more directed to surrounding traffic and less directed to their own traffic situation.

Table 9.2.9 shows the accident cases where the rider eye coverage - either protection or glasses - was a factor in accident causation. The faulty eye protection (5 cases) consisted of the use of a scratched or tinted shield with sunglasses in low light conditions. The one case of eye protection limiting vision involved a rider wearing a set of 22 mm wire frame granny glasses with a 3 diopter correction, who did not see the pickup truck entering from a side street.

Table 9.2.10 shows the damage to the face shield, and the location of that damage. The great majority of the face shields are constructed from acetate sheet, approximately .040 thick and AA finish, in order to provide the necessary optical quality. The primary function is the protection of vision and there should not be high expectations for injury protection. The structural strength of the face shield can not compare with the protection function of the rigid helmet shell with an energy absorbing liner. As a result, the face shield can act only as abrasion protection and minor load spreading at impact sites. Table 9.2.10

TABLE 9.2.5. MOTORCYCLE RIDER EVASIVE ACTION (UNPROTECTED EYES) (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	106	29.6	30.0
Rear Brake	1.	74	20.7	21.0
Front Brake	2.	6	1.7	1.7
Both Brakes	3.	50	14.0	14.2
Swerve	4.	35	9.8	9.9
Lay Down-slide	5.	2	0.6	0.6
Accelerate	6.	4	1.1	1.1
1 and 4	7.	44	12.3	12.5
2 and 4	8.	3	0.8	0.8
3 and 4	9.	25	7.0	7.1
4 and 6	10.	1	0.3	0.3
Other	12.	3	0.8	0.8
Unknown	98.	5	1.4	Missing
	TOTAL	358	100.0	100.0

TABLE 9.2.6. PROPER EXECUTION OF MOTORCYCLE EVASIVE ACTION (UNPROTECTED EYES)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Yes	1.	47	13.1	19.3
No	2.	196	54.7	80.7
Unknown	8.	6	1.7	Missing
N.A.	9.	109	30.4	Missing
	TOTAL	358	100.0	100.0

TABLE 9.2.7. PROPER EVASIVE ACTION SELECTED ? (UNPROTECTED EYES)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Yes	1.	98	27.4	39.8
Probable	2.	4	1.1	1.6
Improbable	4.	2	0.6	0.8
No	5.	142	39.7	57.7
Unknown	8.	4	1.1	Missing
N.A.	9.	108	30.2	Missing
	TOTAL	358	100.0	100.0

TABLE 9.2.8. RIDER ATTENTION TO DRIVING TASK (UNPROTECTED EYES)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Traffic	1.	31	8.7	22.3
Non-Traffic	2.	22	6.1	15.8
Motorcycle Operations	3.	15	4.2	10.8
Inattentive Mode	4.	71	19.8	51.1
Unknown	8.	20	5.6	Missing
N.A.	9.	199	55.6	Missing
	TOTAL	358	100.0	100.0

TABLE 9.2.9. RIDER FAILURE TO SEE BECAUSE OF EYE COVERAGE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	366	40.7	98.4
Eye Pro. Faulty	4.	5	0.6	1.3
Eye Pro. Limited	5.	1	0.1	0.3
Unknown	8.	37	4.1	Missing
N.A.	9.	491	54.6	Missing
	TOTAL	900	100.0	100.0

TABLE 9.2.10. DAMAGE TO RIDER FACE SHIELD (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Type				
None	0.	96	10.7	51.3
Abrasion	1.	75	8.3	40.1
Puncture	2.	1	0.1	0.5
Crack	3.	9	1.0	4.8
Shatter	4.	6	0.7	3.2
Unknown	8.	39	4.3	Missing
N.A.-No Face Shield	9.	674	74.9	Missing
	TOTAL	900	100.0	100.0
Location				
Center	1.	21	2.3	23.9
Upper Right	2.	26	2.9	29.5
Upper Left	3.	19	2.1	21.6
Lower Right	4.	11	1.2	12.5
Lower Left	5.	11	1.2	12.5
Unknown	8.	41	4.6	Missing
N.A.-No Damage or No Face Shield	9.	771	85.7	Missing
	TOTAL	900	100.0	100.0

shows the abrasion absorption, and that the location of face shield damage is essentially symmetrical but more in the upper regions than lower regions.

In a few cases it was noted that the bubble shield offered slightly greater protection by virtue of the higher rigidity, which was due to the double curvature.

Table 9.2.11 shows that 6 cases involved injuries to the motorcycle rider from the eye protection. Two of the cases involved shattering of the lenses of eyeglasses and lacerations due to those fragments. The other four cases involved lacerations and abrasions due to the frames of eyeglasses worn.

TABLE 9.2.11. MOTORCYCLE RIDER EYE INJURIES DUE TO EYE PROTECTION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	241	26.8	97.6
Yes	1.	6	0.7	2.4
Unknown	8.	25	2.8	Missing
N.A.	9.	628	69.8	Missing
	TOTAL	900	100.0	100.0

9.3 Safety Helmet Use

The study area for accident data collection had no laws for mandatory helmet use by motorcycle riders. Whatever forces affect helmet use were free to act upon the motorcycle riders and determine the actual use by those riders involved in accidents. During the interview after the accident, the motorcycle rider was questioned to distinguish several factors relating to safety helmet use. For example, the motorcycle rider was asked to relate the frequency of helmet use, and the results are shown in Table 9.3.1 (Appendix C.5). The riders stated a frequency of helmet use which is difficult to relate to actual use. The median use stated is approximately 74%, and approximately 40% of the accident-involved riders were actually using a safety helmet at the accident occurrence. In the extremes, 28.1% stated that they NEVER wear a safety helmet but 32.8% stated that they ALWAYS wear a safety helmet. Note in Table 9.3.1 the frequencies of riders stating that they wore a safety helmet 90 through 99% of the time, and the only time they had not worn a helmet was that one short trip on which the accident occurred.

Table 9.3.2 shows the safety helmet use by the motorcycle riders in the 900 on-scene, in-depth accident cases. Of the 355 motorcycle riders wearing helmets, 261 were acquired primarily after the offer of replacement with a new helmet furnished by members of the Safety Helmet Council of America. Most of the 94 helmets not acquired were made available for examination and evaluation of crash performance. The data show that 39.8% of the accident-involved motorcycle riders were wearing safety helmets. Preliminary data for the population-at-risk showed approximately 50% of the motorcycle riders in the study were wearing safety helmets. A preliminary hypothesis to explain this difference

TABLE 9.3.2. MOTORCYCLE RIDER HELMET USE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes, acquired by USC	1.	261	29.0	29.3	29.3
Yes, not acquired by USC	2.	94	10.4	10.5	39.8
No	3.	537	59.7	60.2	100.0
Unknown	8.	8	0.9	Missing	100.0
	TOTAL	900	100.0	100.0	

proposed that motorcycle riders who voluntarily use safety helmets are less accident involved, in a way comparable to the lower accident involvement of voluntary seat belt users and alcohol non-users. Also, another explanation proposed was that the voluntary helmet users are less injured and more likely to depart the scene without medical treatment and without the completion of a police traffic accident report. The accident data unfortunately do not confirm or deny either proposition to explain the lower accident involvement of the helmeted riders.

The data of Table 9.3.3 show the equivalent helmet use data for the 3600 police traffic accident report cases. The accident forms for all law enforcement jurisdictions in the study area did not include requirements for noting helmet use. Consequently, the police traffic accident report would not include helmet use information unless the investigating officer made narrative note of that fact; such information usually resulted from the investigating officer's observation that head injuries resulted from failure to wear a safety helmet, or head injuries were prevented by the use of a safety helmet. For those cases including such information (23.2%), the accident-involved motorcycle rider was wearing a helmet in 42.0% of those cases.

TABLE 9.3.3. MOTORCYCLE RIDER HELMET USE (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes	1.	351	9.7	42.0	42.0
No	2.	484	13.4	58.0	100.0
Not Reported	8.	2765	76.8	Missing	100.0
	TOTAL	3600	100.0	100.0	

Table 9.3.4 shows the safety helmet use by the passengers in the 900 on-scene, in-depth accident cases. These data show the passenger use (15.9%) is far less than the rider use (39.8%). Table 9.3.5 shows the equivalent data for the 3600 traffic accident report cases and shows reporting for only 22.7% of the cases, and passenger helmet use in 19.7% of those.

TABLE 9.3.4. PASSENGER HELMET USE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes, acquired	1.	12	1.3	7.9	7.9
Yes, not acquired	2.	12	1.3	7.9	15.9
No	3.	127	14.1	84.1	100.0
Unknown	8.	1	0.1	Missing	100.0
N.A. (No Passenger)	9.	748	83.1	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.3.5. PASSENGER HELMET USE (TARs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes	1.	25	0.7	19.7	19.7
No	2.	102	2.8	80.3	100.0
Unknown-Not Reported	8.	434	12.1	Missing	100.0
N.A. (No Passenger)	9.	3039	84.4	Missing	100.0
	TOTAL	3600	100.0	100.0	

Table 9.3.6 shows the motorcycle rider safety helmet use for the 54 fatal accidents within the 900 on-scene, in-depth accident cases. In these cases 22.6% of the fatally injured riders were wearing safety helmets. Of course, the fatal injuries are not exclusively due to head injuries. But the advantage of the safety helmet was obvious in many ways. Many fatal accidents without helmet use involved low energy yet exceptional injury to the unprotected head; a few fatal accidents with helmet use involved very high energy and rare fatal injury to the helmeted head. For example, an unhelmeted rider fell while standing on the seat riding his new Sportster at low speed, and suffered a depressed fracture of the left side of the unprotected skull. In contrast, a rare case was the alcohol-involved rider who ran off the road at high speed and whose helmeted head (and chest) were crushed between the tumbling Gold Wing and concrete curb.

TABLE 9.3.6. MOTORCYCLE RIDER HELMET USE-FATAL ACCIDENTS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes	1.	12	22.2	22.6	22.6
No	3.	41	75.9	77.4	100.0
Unknown	8.	1	1.9	Missing	100.0
	TOTAL	54	100.0	100.0	

Table 9.3.7 lists the reasons stated by the motorcycle rider for <u>not</u> wearing a safety helmet. "No expectation of accident involvement" and "helmet not in possession" have essentially identical foundations and total 53.1% of those cases. A typical situation in this category is the motorcycle rider who states that he has a helmet at home but did not use it because he was going just for a short ride. "Inconvenient and uncomfortable" is a common complaint on hot days, and is given support by the fact that helmet use declines significantly with high ambient temperatures. Table 9.3.8 lists the reasons stated by the passengers for <u>not</u> wearing a safety helmet, and the lack of expected accident involvement is the principal factor.

TABLE 9.3.7. REASON RIDER DID NOT WEAR HELMET

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Inconvenient	1.	115	12.8	25.6	25.6
Excessive Cost	2.	30	3.3	6.7	32.2
Reduce Awareness	3.	36	4.0	8.0	40.2
No Expectation	4.	171	19.0	38.0	78.2
Not in Possession	5.	68	7.6	15.1	93.3
Wary of Helmet Injury	6.	17	1.9	3.8	97.1
Other	7.	13	1.4	2.9	100.0
Unknown	8.	96	10.7	Missing	100.0
N.A.	9.	354	39.3	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.3.9 shows the conditions stated by the rider for wearing a helmet: 28.9% stated <u>never</u>; 36.7% stated <u>always</u>. The response of "highway, freeway" should be combined with "other" for full consideration of expectation of accident involvement. The greatest part of "other" response was that the rider stated helmet use for <u>all but short trips</u>. For example, a trip plan involving highway travel for great distance portends of possible hazard so a helmet would be used; but a short trip for recreation or errand would not relate threat so a helmet would not be worn.

TABLE 9.3.8. REASON PASSENGER DID NOT WEAR HELMET

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Inconvenient	1.	13	1.4	12.0	12.0
Excessive Cost	2.	9	1.0	8.3	20.4
Reduce Awareness	3.	2	0.2	1.9	22.2
No Expectation	4.	48	5.3	44.4	66.7
Not in Possession	5.	18	2.0	16.7	83.3
Wary of Helmet Injury	6.	3	0.3	2.8	86.1
Other	7.	15	1.7	13.9	100.0
Unknown	8.	20	2.2	Missing	100.0
N.A. (No Passenger)	9.	772	85.8	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.3.9. MOTORCYCLE RIDER CONDITIONS FOR WEARING HELMET

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Never	0.	204	22.7	28.9	28.9
Surface Roads	1.	8	0.9	1.1	30.0
Highway, Freeway	2.	131	14.6	18.6	48.6
Always	3.	259	28.8	36.7	85.3
Other*	4.	104	11.6	14.7	100.0
Unknown	8.	194	21.6	Missing	100.0
	TOTAL	900	100.0	100.0	

*Usually, "All But Short Trips."

In order to investigate the actual conditions under which safety helmets were worn by the accident-involved motorcycle riders, several crosstabulations were developed. Table 9.3.10 compares motorcycle rider helmet use and accident time of day for the 892 on-scene, in-depth cases where helmet use was identified. Note that the accident-involved riders have higher than average helmet use in the time span between 0601 and 1301, but this group consists of only 32.2% of the accidents. The accident-involved riders have average or below average use in the high frequency accident times.

Another factor in these data is that the accident-involved motorcycle riders have lower helmet use in the nighttime (34.9% from 1901 to 0701) than in the daytime (41.0% from 0701 to 1901).

Table 9.3.11 provides a crosstabulation of weather conditions at the time of the accident and motorcycle rider helmet use. These data show that these

TABLE 9.3.10. SAFETY HELMET USE BY ACCIDENT TIME OF DAY (OSIDs)

Time	Count Row Pct Col Pct Tot Pct	Helmet Yes	Helmet No	Row Total	Time	Count Row Pct Col Pct Tot Pct	Helmet Yes	Helmet No	Row Total
0 thru 100	1.	4 33.3 1.1 0.4	8 66.7 1.5 0.9	12 1.3	1201 thru 1300	13.	39 42.4 11.0 4.4	53 57.6 9.9 5.9	92 10.3
101 thru 200	2.	1 16.7 0.3 0.1	5 83.3 0.9 0.6	6 0.7	1301 thru 1400	14.	21 31.3 5.9 2.4	46 68.7 8.6 5.2	67 7.5
201 thru 300	3.	1 9.1 0.3 0.1	10 90.9 1.9 1.1	11 1.2	1401 thru 1500	15.	28 35.0 7.9 3.1	52 65.0 9.7 5.8	80 9.0
301 thru 400	4.	4 57.1 1.1 0.4	3 42.9 0.6 0.3	7 0.8	1501 thru 1600	16.	36 38.7 10.1 4.0	57 61.3 10.6 6.4	93 10.4
401 thru 500	5.	0 0.0 0.0 0.0	2 100.0 0.4 0.2	2 0.2	1601 thru 1700	17.	27 31.0 7.6 3.0	60 69.0 11.2 6.7	87 9.8
501 thru 600	6.	0 0.0 0.0 0.0	1 100.0 0.2 0.1	1 0.1	1701 thru 1800	18.	29 38.7 8.2 3.3	46 61.3 8.6 5.2	75 8.4
601 thru 700	7.	7 50.0 2.0 0.8	7 50.0 1.3 0.8	14 1.6	1801 thru 1900	19.	18 42.9 5.1 2.0	24 57.1 4.5 2.7	42 4.7
701 thru 800	8.	9 52.9 2.5 1.0	8 47.1 1.5 0.9	17 1.9	1901 thru 2000	20.	14 31.1 3.9 1.6	31 68.9 5.8 3.5	45 5.0
801 thru 900	9.	20 60.6 5.6 2.2	13 39.4 2.4 1.5	33 3.7	2001 thru 2100	21.	9 27.3 2.5 1.0	24 72.7 4.5 2.7	33 3.7
901 thru 1000	10.	22 64.7 6.2 2.5	12 35.3 2.2 1.3	34 3.8	2101 thru 2200	22.	16 69.6 4.5 1.8	7 30.4 1.3 0.8	23 2.6
1001 thru 1100	11.	15 44.1 4.2 1.7	19 55.9 3.5 2.1	34 3.8	2201 thru 2300	23.	2 22.2 0.6 0.2	7 77.8 1.3 0.8	9 1.0
1101 thru 1200	12.	30 47.6 8.5 3.4	33 52.4 6.1 3.7	63 7.1	2301 thru 2400	24.	3 25.0 0.8 0.3	9 75.0 1.7 1.0	12 1.3
	Column Total	355 39.8	537 60.2	892 100.0		Column Total	355 39.8	537 60.2	892 100.0

TABLE 9.3.11. SAFETY HELMET USE BY AMBIENT WEATHER CONDITIONS (OSIDs)

Weather	Count / Row Pct / Col Pct / Tot Pct	Helmet: Yes	Helmet: No	Row Total
Clear	Count	290	454	744
	Row Pct	39.0	61.0	83.4
	Col Pct	81.7	84.5	
	Tot Pct	32.5	50.9	
Rain	Count	4	5	9
	Row Pct	44.4	55.6	1.0
	Col Pct	1.1	0.9	
	Tot Pct	0.4	0.6	
Drizzle	Count	7	4	11
	Row Pct	63.6	36.4	1.2
	Col Pct	2.0	0.7	
	Tot Pct	0.8	0.4	
Cloudy or Partly	Count	42	47	89
	Row Pct	47.2	52.8	10.0
	Col Pct	11.8	8.8	
	Tot Pct	4.7	5.3	
Overcast	Count	12	27	39
	Row Pct	30.8	69.2	4.4
	Col Pct	3.4	5.0	
	Tot Pct	1.3	3.0	
Column Total		355	537	892
		39.8	60.2	100.0

accident-involved motorcycle riders used helmets only slightly more than average (43.9% vs. 39.8%) when there were actual or possible adverse weather conditions.

Table 9.3.12 shows a comparison of ambient temperature at the accident site and motorcycle rider helmet use. These data show that the accident-involved motorcycle riders used helmets slightly more than average (42.9% vs. 39.9%) when the ambient temperatures were less than $70^{\circ}F$.

Table 9.3.13 provides a summary of motorcycle rider age and helmet use for the 900 on-scene, in-depth accident cases. These data show a significant effect of age on helmet use with the youngest accident-involved riders having the lowest helmet use. Those motorcycle riders less than 27 years of age show significantly less than average helmet use (34.9% vs. 39.9%). The detailed crosstabulation of motorcycle rider age and helmet use is shown in Table 9.3.14 (Appendix C.5).

TABLE 9.3.12. SAFETY HELMET USE BY AMBIENT TEMPERATURE (OSIDs)

Temperature	Count Row Pct Col Pct Tot Pct	Helmet Yes	 No	Row Total
41 thru 50		6 46.2 1.7 0.7	7 53.8 1.3 0.8	13 1.5
51 thru 60		52 44.1 15.0 6.0	66 55.9 12.6 7.6	118 13.6
61 thru 70		134 42.1 38.6 15.4	184 57.9 35.2 21.1	318 36.6
71 thru 80		117 36.4 33.7 13.4	204 63.6 39.0 23.4	321 36.9
81 thru 90		35 39.3 10.1 4.0	54 60.7 10.3 6.2	89 10.2
91 thru 100		3 27.3 0.9 0.3	8 72.7 1.5 0.9	11 1.3
	Column Total	347 39.9	523 60.1	870 100.0

Table 9.3.15 shows motorcycle rider sex and helmet use. While it is shown that the accident-involved female motorcycle riders had higher than average frequency of helmet use, the data are not sufficient in number to provide a significant result.

Table 9.3.16 provides a crosstabulation of motorcycle rider education and helmet use for the 900 on-scene, in-depth accident cases. These data portray a powerful effect of the educational experience of the accident-involved motorcycle rider; the voluntary helmet use is the highest at the highest level of education. It is highly significant that college education experienced riders had much higher than average helmet use (50.1% vs. 41.1%). This effect of educational experience reflects the beneficial consciousness of security associated with higher education,

TABLE 9.3.13. SUMMARY OF SAFETY HELMET USE BY MOTORCYCLE RIDER AGE (OSIDs)

Age	Count / Row Pct / Col Pct / Tot Pct	Helmet: Yes	Helmet: No	Helmet: Unknown	Row Total
0 thru 16	Count	4	10	0	14
	Row Pct	28.6	71.4	0.0	1.6
	Col Pct	1.1	1.9	0.0	
	Tot Pct	0.4	1.1	0.0	
17 thru 20	Count	53	101	1	155
	Row Pct	34.2	65.2	0.6	17.2
	Col Pct	14.9	18.8	12.5	
	Tot Pct	5.9	11.2	0.1	
21 thru 26	Count	119	217	3	339
	Row Pct	35.1	64.0	0.9	37.7
	Col Pct	33.5	40.4	37.5	
	Tot Pct	13.2	24.1	0.3	
27 thru 39	Count	125	169	2	296
	Row Pct	42.2	57.1	0.7	32.9
	Col Pct	35.2	31.5	25.0	
	Tot Pct	13.9	18.8	0.2	
40 thru 49	Count	29	21	1	51
	Row Pct	56.9	41.2	2.0	5.7
	Col Pct	8.2	3.9	12.5	
	Tot Pct	3.2	2.3	0.1	
50 thru 59	Count	18	8	0	26
	Row Pct	69.2	30.8	0.0	2.9
	Col Pct	5.1	1.5	0.0	
	Tot Pct	2.0	0.9	0.0	
60 thru 97	Count	5	5	0	10
	Row Pct	50.0	50.0	0.0	1.1
	Col Pct	1.4	0.9	0.0	
	Tot Pct	0.6	0.6	0.0	
Unknown	Count	2	5	1	8
	Row Pct	25.0	62.5	12.5	0.9
	Col Pct	0.6	0.9	12.5	
	Tot Pct	0.2	0.6	0.1	
N.A.	Count	0	1	0	1
	Row Pct	0.0	100.0	0.0	0.1
	Col Pct	0.0	0.2	0.0	
	Tot Pct	0.0	0.1	0.0	
	Column Total	355	537	8	900
		39.4	59.7	0.9	100.0

TABLE 9.3.15. SAFETY HELMET USE BY MOTORCYCLE RIDER SEX (OSIDs)

Sex	Count Row Pct Col Pct Tot Pct	Helmet Yes	Helmet No	Row Total
Male		340 39.6 95.8 38.1	518 60.4 96.5 58.1	858 96.2
Female		15 44.1 4.2 1.7	19 55.9 3.5 2.1	34 3.8
	Column Total	355 39.8	537 60.2	892 100.0

and presents the formidable problem for K-12 education to establish personal priorities for protective equipment.

Table 9.3.17 shows the motorcycle rider helmet use as a function of occupation. The "unemployed" riders demonstrate the lowest helmet use of any group, with the helmet use rate of 17.6% being outstanding and significantly below the average of all accident-involved riders. The "laborers" involved in these accidents also demonstrated low helmet use (32.4%) which was significantly below the average (40.6%). The majority of the "unemployed" riders were "laborers" when employed.

Table 9.3.18 shows the crosstabulation of motorcycle rider training with helmet use for the 900 on-scene, in-depth accident cases. Those accident-involved motorcycle riders who were "self-taught" or taught by "friends-family" represent the greatest part of the accidents (91.9%). However, this group of untrained riders represents far more than their fair share of unprotected heads. The trained motorcycle riders (although they are scarce) show very high rates of helmet use and the comparison with untrained riders is highly significant. As an example, an Air Force airman who was a recent graduate of the Norton Air Force Base Motorcycle Training Program was passing through the study area and contributed to the accident data with a crash on the freeway. The airman was well protected with a heavy jacket, gloves, boots and a highly qualified full facial coverage helmet. The helmet was badly damaged in the high speed crash and fall, but all injuries were minor and the benefit of the training was clear.

Table 9.3.19 shows the crosstabulation of the street motorcycle rider experience and helmet use. These data show a great difference in safety helmet use at the 2 year experience level. It is significant that riders with less than 2 years experience average 35.3% helmet use, but riders with more than 2 years experience have a much higher average - 46.9% - of helmet use.

TABLE 9.3.16. SAFETY HELMET USE BY MOTORCYCLE RIDER EDUCATION (OSIDs)

Count Row Pct Col Pct Tot Pct	Helmet Yes	 No	Row Total
Grad School	18 78.3 5.3 2.2	5 21.7 1.0 0.6	23 2.8
College Graduate	21 48.8 6.2 2.5	22 51.2 4.5 2.7	43 5.2
Partial College	143 48.1 42.2 17.3	154 51.9 31.7 18.7	297 36.0
High School Graduate	92 40.2 27.1 11.2	137 59.8 28.2 16.6	229 27.8
Partial High School	58 28.7 17.1 7.0	144 71.3 29.6 17.5	202 24.5
Junior High School	4 23.5 1.2 0.5	13 76.5 2.7 1.6	17 2.1
Less than 7 Yrs	3 21.4 0.9 0.4	11 78.6 2.3 1.3	14 1.7
Column Total	339 41.1	486 58.9	825 100.0

TABLE 9.3.17. SAFETY HELMET USE BY RIDER OCCUPATION (OSIDs)

Count Row Pct Col Pct Tot Pct	Helmet Yes	 No	Row Total	Count Row Pct Col Pct Tot Pct	Helmet Yes	 No	Row Total
Professional	38 60.3 10.8 4.4	25 39.7 4.8 2.9	63 7.3	Laborers	44 32.4 12.5 5.1	92 67.6 17.8 10.6	136 15.7
Mgr, Administrator	15 62.5 4.3 1.7	9 37.5 1.7 1.0	24 2.8	Service Workers	42 49.4 11.9 4.8	43 50.6 8.3 5.0	85 9.8
Sales Worker	4 30.8 1.1 0.5	9 69.2 1.7 1.0	13 1.5	Housewife	2 66.7 0.6 0.2	1 33.3 0.2 0.1	3 0.3
Clerical	28 45.2 8.0 3.2	34 54.8 6.6 3.9	62 7.1	Student	72 39.1 20.5 8.3	112 60.9 21.7 12.9	184 21.2
Craftsman	72 46.8 20.5 8.3	82 53.2 15.9 9.4	154 17.7	Military	7 53.8 2.0 0.8	6 46.2 1.2 0.7	13 1.5
Operatives	2 25.0 0.6 0.2	6 75.0 1.2 0.7	8 0.9	Retired	1 20.0 0.3 0.1	4 80.0 0.8 0.5	5 0.6
Transport Operators	9 33.3 2.6 1.0	18 66.7 3.5 2.1	27 3.1	Unemployed	16 17.6 4.5 1.8	75 82.4 14.5 8.6	91 10.5
Column Total	352 40.6	516 59.4	868 100.0	Column Total	352 40.6	516 59.4	868 100.0

Count / Row Pct / Col Pct / Tot Pct	Helmet Yes	Helmet No	Row Total
Self Taught	151 37.8 45.1 18.7	248 62.2 52.5 30.7	399 49.4
Friends - Family	139 40.5 41.5 17.2	204 59.5 43.2 25.3	343 42.5
Motorcycle Course	28 68.3 8.4 3.5	13 31.7 2.8 1.6	41 5.1
By Professionals	15 75.0 4.5 1.9	5 25.0 1.1 0.6	20 2.5
Other	2 50.0 0.6 0.2	2 50.0 0.4 0.2	4 0.5
Column Total	335 41.5	472 58.5	807 100.0

TABLE 9.3.18. SAFETY HELMET USE BY MOTORCYCLE RIDER TRAINING (OSIDs)

TABLE 9.3.19. SAFETY HELMET USE BY MOTORCYCLE RIDER STREET RIDING EXPERIENCE (OSIDs)

Count / Row Pct / Col Pct / Tot Pct	Helmet Yes	Helmet No	Row Total
0 to 6 months	54 34.6 15.7 6.6	102 65.4 21.5 12.5	156 19.1
7 to 12 months	26 31.3 7.6 3.2	57 68.7 12.0 7.0	83 10.2
1 to 2 years	42 39.3 12.2 5.1	65 60.7 13.7 8.0	107 13.1
2 to 3 years	44 47.8 12.8 5.4	48 52.2 10.1 5.9	92 11.3
3 to 4 years	28 43.8 8.2 3.4	36 56.3 7.6 4.4	64 7.8
More than 4 years	149 47.3 43.4 18.2	166 52.7 35.0 20.3	315 38.6
Column Total	343 42.0	474 58.0	817 100.0

Table 9.3.20 distinguishes the particular experience on the accident-involved motorcycle. These data show an outstanding contribution by the accident-involved riders with less than 6 months experience with the accident motorcycle. All other levels of experience greater than 6 months show higher than average helmet use.

TABLE 9.3.20. SAFETY HELMET USE BY MOTORCYCLE RIDER EXPERIENCE ON ACCIDENT-INVOLVED MOTORCYCLE (OSIDs)

Count Row Pct Col Pct Tot Pct	Helmet: Yes	Helmet: No	Row Total
0 to 6 months	166 33.9 47.6 19.5	323 66.1 64.2 37.9	489 57.4
7 to 12 months	65 47.8 18.6 7.6	71 52.2 14.1 8.3	136 16.0
1 to 2 years	58 51.8 16.6 6.8	54 48.2 10.7 6.3	112 13.1
2 to 3 years	35 56.5 10.0 4.1	27 43.5 5.4 3.2	62 7.3
3 to 4 years	11 42.3 3.2 1.3	15 57.7 3.0 1.8	26 3.1
More than 4 years	14 51.9 4.0 1.6	13 48.1 2.6 1.5	27 3.2
Column Total	349 41.0	503 59.0	852 100.0

Table 9.3.21 shows the crosstabulation of dirt bike experience and helmet use in the 900 accident cases. In these data the motorcycle riders with stated dirt bike experience have only slightly higher than average helmet use rate. If dirt bike riding experience is a beneficial training or experience effect, it is not significantly related to helmet use by these data.

TABLE 9.3.21. SAFETY HELMET USE BY DIRT BIKE EXPERIENCE (OSIDs)

	Count Row Pct Col Pct Tot Pct	Helmet Yes	 No	Row Total
Dirt Bike Experience	Yes	106 44.5 30.8 12.8	132 55.5 27.1 15.9	238 28.6
	No	238 40.1 69.2 28.6	355 59.9 72.9 42.7	593 71.4
	Column Total	344 41.4	487 58.6	831 100.0

Table 9.3.22 provides one of the most important aspects of helmet use: the length of the intended trip. These data portray the highest helmet use for long trips (which may portend hazard or threat) and the lowest helmet use for the short trip (where no threat or hazard is related). Approximately half the accident cases show trip lengths less than five miles, and the lack of safety helmet use for these short trips is outstanding and far below the average. Note that helmet use for long trips is very high and implies that helmet use would tend to be high on long distance traffic ways, e.g., interstate highways, freeways, etc., and helmet use would tend to be low in urban and suburban traffic where short trips are common.

Table 9.3.23 shows safety helmet use as a function of trip origin. The highest rates of helmet use are associated with "work" as the origin. Table 9.3.24 shows that same highest helmet use associated with "work" as the destination.

Tables 9.3.25 (Appendix C.5) and 9.3.26 (Appendix C.5) show the trip plans for the helmeted (25) and unhelmeted (26) riders involved in the 900 on-scene, in-depth accident cases. These data portray a high rate of helmet use for the home-work trip plan, but low rates of helmet use for trip plans involving recreation and visiting friend and relatives, especially when that recreation, etc. is the origin.

Table 9.3.27 shows the type of helmet coverage used by the motorcycle riders in the 900 on-scene, in-depth accident cases.

TABLE 9.3.22. SAFETY HELMET USE BY RIDER TRIP LENGTH (OSIDs)

Count Row Pct Col Pct Tot Pct	Helmet Yes	 No	Row Total
0 to 1 mile	46 28.6 13.0 5.2	115 71.4 21.4 12.9	161 18.0
1.1 to 5 miles	103 36.4 29.0 11.5	180 63.6 33.5 20.2	283 31.7
5 to 50 miles	163 53.4 45.9 18.3	142 46.6 26.4 15.9	305 34.2
Over 50 miles	20 74.1 5.6 2.2	7 25.9 1.3 0.8	27 3.0
Unknown	23 19.8 6.5 2.6	93 80.2 17.3 10.4	116 13.0
Column Total	355 39.8	537 60.2	892 100.0

TABLE 9.3.23. SAFETY HELMET USE BY TRIP ORIGIN (OSIDs)

Origin	Count Row Pct Col Pct Tot Pct	Helmet: Yes	Helmet: No	Row Total
Home		140 44.6 40.7 17.1	174 55.4 36.6 21.2	314 38.3
Work		99 60.7 28.8 12.1	64 39.3 13.4 7.8	163 19.9
Shopping		28 31.5 8.1 3.4	61 68.5 12.8 7.4	89 10.9
Recreation		19 25.3 5.5 2.3	56 74.7 11.8 6.8	75 9.1
Friends, Relative		30 25.0 8.7 3.7	90 75.0 18.9 11.0	120 14.6
Bar, Drinking Party		5 27.8 1.5 0.6	13 72.2 2.7 1.6	18 2.2
School		23 56.1 6.7 2.8	18 43.9 3.8 2.2	41 5.0
	Column Total	344 42.0	476 58.0	820 100.0

TABLE 9.3.24. SAFETY HELMET USE BY, DESTINATION (OSIDs)

Destination	Count / Row Pct / Col Pct / Tot Pct	Helmet: Yes	Helmet: No	Row Total
Home		106 38.7 30.9 12.8	168 61.3 34.6 20.3	274 33.1
Work		92 60.5 26.8 11.1	60 39.5 12.3 7.2	152 18.3
Shopping		61 43.0 17.8 7.4	81 57.0 16.7 9.8	142 17.1
Recreation		28 23.3 8.2 3.4	92 76.7 18.9 11.1	120 14.5
Friends, Relative		46 40.0 13.4 5.5	69 60.0 14.2 8.3	115 13.9
Bar, Drinking Party		0 0.0 0.0 0.0	1 100.0 0.2 0.1	1 0.1
School		10 40.0 2.9 1.2	15 60.0 3.1 1.8	25 3.0
	Column Total	343 41.4	486 58.6	829 100.0

TABLE 9.3.27. HELMET TYPE USED

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Partial	1.	32	3.6	9.4	9.4
Full	2.	197	21.9	57.6	67.0
Full Face 105°	3.	14	1.6	4.1	71.1
Full Face 120°	4.	99	11.0	28.9	100.0
Unknown	8.	22	2.4	Missing	100.0
N.A., No Helmet	9.	536	59.6	Missing	100.0
	TOTAL	900	100.0	100.0	

These data portray the helmet user in these accidents as distinctly different from the non-user. That accident-involved rider without head protection is young and without motorcycle experience and training, has low job skills and may be unemployed, and is on a short trip involving errands, recreation, and visits.

9.4 Helmet Manufacturer and Construction

Table 9.4.1 shows the manufacturer of the helmets worn by the motorcycle riders involved in the 900 on-scene, in-depth accident cases. In many instances, identification of the helmet was difficult and required consulting with the Safety Helmet Council of America and its membership to determine the origin. In spite of intensive examination of each helmet, positive identification of the helmet was not possible for 22.3% of the helmets. Of course, modern helmets complying with FMVSS 218 were readily identified. In addition, well known major brands of helmets were easily identified, and helmets made by members of the Safety Helmet Council of America were identified by the SHCA label and that reference provided date of manufacture. Also, those high performance helmets with labels specifying the Snell Memorial Foundation approval could be identified and dated by that reference.

Table 9.4.2 shows the year of manufacture for the motorcycle riders helmet. 48.6% of these accident-involved helmets could not be identified sufficiently for date of manufacture, and these helmets appeared to be more than just a few years old. Most of the unidentified and undated helmets appeared to be manufactured in the early 1970's, or late 1960's.

Table 9.4.3 shows the qualifications for the motorcycle riders helmets, as determined by labeling or manufacturer. Of the 364 accident-involved helmets, 62 (17.0%) had labels relating DOT-FMVSS-218 qualification. Most of these helmets with "DOT" labels were of recent manufacture. SHCA labels were on 49.3% of the accident-involved helmets, and 53.1% of the helmets had notation of ANSI Z-90 qualification. The Snell Memorial Foundation qualification represents the highest qualification of protection performance, and various years of Snell labels were present on 22.8% of the accident helmets.

TABLE 9.4.1. MOTORCYCLE RIDER HELMET MANUFACTURER (OSIDs)

Category Level	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Accessory Dist.	1.	4	0.4	1.4
American Safety	2.	21	2.3	7.4
American Sports	3.	9	1.0	3.2
Ralph Barnes	4.	9	1.0	3.2
Bell	5.	93	10.3	32.9
Cycraft Mfg.	8.	1	0.1	0.4
Electrofilm	9.	5	0.6	1.8
Falcon	10.	2	0.2	0.7
Lear Siegler	13.	10	1.1	3.5
McHal	14.	6	0.7	2.1
Premier Pacific	17.	7	0.8	2.5
Premier Seat	18.	2	0.2	0.7
Rebcor	19.	14	1.6	4.9
Roper	20.	8	0.9	2.8
Safetech	21.	18	2.0	6.4
Shoei	23.	42	4.7	14.8
T&C Mfg.	25.	5	0.6	1.8
Trabaca	26.	3	0.3	1.1
Yoder	27.	4	0.4	1.4
Daytona Sports	29.	3	0.3	1.1
Royal Industries	31.	5	0.6	1.8
NJL-Abadon Prods.	33.	1	0.1	0.4
Others	97.	11	1.2	3.9
Unknown	98.	81	9.0	Missing
N.A., No Helmet	99.	536	59.6	Missing
	TOTAL	900	100.0	100.0

TABLE 9.4.2. MOTORCYCLE RIDER HELMET YEAR OF MANUFACTURE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
19__	68.	1	0.1	0.5	0.5
	70.	5	0.6	2.7	3.2
	71.	6	0.7	3.2	6.4
	72.	12	1.3	6.4	12.8
	73.	24	2.7	12.8	25.7
	74.	49	5.4	26.2	51.9
	75.	39	4.3	20.9	72.7
	76.	41	4.6	21.9	94.7
	77.	10	1.1	5.3	100.0
Unknown	98.	177	19.7	Missing	100.0
N.A.	99.	536	59.6	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.4.4 shows that the majority of the accident-involved helmets (76.6%) had fiberglass shell construction. The liner material at the location of the most severe impact is shown in Table 9.4.5. Ordinarily this liner material at the most severe impact site is the major energy absorbing material of the crown, but some impacts occurred where there was only comfort padding, chin padding, or nothing at all. The crushable expanded polystyrene foam was the liner material most usually found during helmet examination. Table 9.4.6 (Appendix C.5) shows the liner thickness measured at the most severe impact site. Those areas of impact with less than 5/8 inch liner thickness were areas of comfort padding, chin padding, or at areas near the edge of the liner. Very few helmets had basic liner thicknesses less than 5/8 inch, and these helmets were very old designs or equestrian helmets or moped helmets not intended for traffic use. The median liner thickness was almost .78 inch and approximately one-third of the helmets had liner thickness of one inch or more. Table 9.4.7 (Appendix C.5) shows the liner density at the most severe impact site, with the median density of 3.84 lbs. per cubic foot. Of course, the styrofoam bead materials are essentially the only liner materials available at low density, and represent the greatest part of those liners of density less than 4 lbs. per cubic foot.

Approximately 15% of the liners had density greater than 6 lbs. per cubic foot. The liner materials in this range of density were ethafoam, nitrile-vinyl rubber, and polyurethane.

Table 9.4.8 shows the precrash condition of the motorcycle rider helmets involved in the 900 on-scene, in-depth accident cases. As shown with these data, 25.0% of the accident-involved helmets showed evidence of significant damage in advance of the accident. The damage to the fiberglass shell helmets was innocuous and did not affect accident performance. Typical damage involved punctures and lacerations of the liner interior surface from contact with motorcycle components and accessories, i.e., mirrors and sissybars. Damage to the fiberglass shell consisted mainly of superficial abrasions and chipping of the gelcoat and small delaminations at the vertex of the shell (from handling and dropping the helmet).

TABLE 9.4.3. MOTORCYCLE RIDER HELMET QUALIFICATION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
FMVSS-218 Labeled Helmet					
Yes	1.	62	6.9	20.0	
No	2.	221	24.6	74.7	
No, Disclaimer Attached	3.	13	1.4	4.4	
Unknown	8.	68	7.6	Missing	
N.A.	9.	536	59.5	Missing	
	TOTAL	900	100.0	100.0	
Safety Helmet Council of America Qualified					
Yes	1.	146	16.2	49.3	49.3
No	2.	150	16.7	50.7	100.0
Unknown	8.	68	7.6	Missing	100.0
N.A.	9.	536	59.5	Missing	100.0
	TOTAL	900	100.0	100.0	
ANSI Z-90 Qualification					
Yes, 1966	1.	33	3.7	11.2	11.2
Yes, 1971	2.	123	13.7	41.8	53.1
No	3.	138	15.3	46.9	100.0
Unknown	8.	70	7.8	Missing	100.0
N.A.	9.	536	59.6	Missing	100.0
	TOTAL	900	100.0	100.0	
Snell Foundation Qualification					
Yes, 1962	1.	2	0.2	0.7	0.7
Yes, 1968	2.	17	1.9	5.8	6.5
Yes, 1970	3.	47	5.2	16.0	22.5
Yes, 1975	4.	1	0.1	0.3	22.8
No	5.	227	25.2	77.2	100.0
Unknown	8.	70	7.8	Missing	100.0
N.A.	9.	536	59.6	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.4.4. MOTORCYCLE RIDER HELMET SHELL MATERIAL (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Fiberglass	1.	249	27.7	76.6
Polycarbonate	2.	76	8.4	23.4
Unknown	8.	39	4.3	Missing
N.A.	9.	536	59.6	Missing
	TOTAL	900	100.0	100.0

TABLE 9.4.5. HELMET LINER MATERIAL AT MOST SEVERE IMPACT SITE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	4	0.4	1.5
Lg. Bd. Styrofoam	1.	32	3.6	12.2
Sm. Bd. Styrofoam	2.	183	20.3	69.6
Polyurethane	3.	18	2.0	6.8
Ethafoam	4.	15	1.7	5.7
Neoprene Sponge	5.	5	0.6	1.9
Polypropylene	6.	4	0.4	1.5
Other	7.	2	0.2	0.8
Unknown	8.	52	5.8	Missing
N.A.	9.	585	65.0	Missing
	TOTAL	900	100.0	100.0

TABLE 9.4.8. PRECRASH CONDITION OF MOTORCYCLE RIDER SAFETY HELMET (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Damaged	1.	80	8.9	25.0
Not Damaged	2.	240	26.7	75.0
Unknown	8.	43	4.8	Missing
N.A.	9.	537	59.7	Missing
	TOTAL	900	100.0	100.0

The precrash damage evident in <u>some</u> polycarbonate shell helmets was more serious and affected crash performance. Crazing and cracking in areas of high residual tensile stress, particularly at retention system rivet holes, were associated with premature shell fracture at impact with resultant retention failure or impact attenuation failure. Even this problem was very rare and the usual accident performance of the polycarbonate shell helmet was satisfactory and no other type of precrash damage affected accident performance.

9.5 Safety Helmet Retention System Performance

The retention system has the function of containing the head within the envelope of protection when the crash impact occurs. It is widely accepted that the helmet must fit well and the retention system must be securely fastened for the helmet to be retained on the head during crash impact. If the helmet fits loosely, the crash impact may cause the helmet to rotate and slip off the head even though the retention system is fastened. If the retention system is <u>not</u> fastened, the most minor impact is sure to dislodge the helmet and leave the head unprotected. Table 9.5.1 shows that 5.9% of the accident-involved motorcycle riders who wore a helmet did not have the retention system fastened.

TABLE 9.5.1. MOTORCYCLE RIDER HELMET RETENTION SYSTEM (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Retention Systems Fastened-Rider				
Yes	1.	319	35.4	94.1
No	2.	20	2.2	5.9
Unknown	8.	25	2.8	Missing
N.A.	9.	536	59.6	Missing
	TOTAL	900	100.0	100.0
Type Retention System-Rider				
None	0.	1	0.1	0.3
D-Rings	1.	311	34.6	92.8
Snaps	2.	5	0.6	1.5
1 and 2	3.	5	0.6	1.5
Quick Release	4.	5	0.6	1.5
Other	5.	8	0.9	2.4
Unknown	8.	29	3.2	Missing
N.A.	9.	536	59.6	Missing
	TOTAL	900	100.0	100.0

Also shown in Table 9.5.1 is the type of retention system on those motorcycle rider helmets. "D-rings" is the most typical configuration encountered, and experience has shown this configuration to have the highest reliability and strength. The one helmet without retention system had the conventional webbing and D-rings removed.

Table 9.5.2 shows that 5.3% of the helmets were not retained on the head during the crash impact. The most frequent cause of these helmet ejections was the unfastened retention system, which would seem to guarantee loss of the helmet during crash impact. Incredibly, some of the riders did retain the unfastened helmet during the accident.

TABLE 9.5.2. MOTORCYCLE RIDER HELMET RETENTION PERFORMANCE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Helmet Stay on Head-Rider				
Yes	1.	324	36.0	94.7
No	2.	18	2.0	5.3
Unknown	8.	22	2.4	Missing
N.A.	9.	536	59.6	Missing
	TOTAL	900	100.0	100.0
Type Retention Failure-Rider				
D-Rings	1.	5	0.6	55.6
Broke Rivet	4.	1	0.1	11.1
Webbing Failed	5.	2	0.2	22.2
Shell Failure at Rivet Hole	6.	1	0.1	11.1
Unknown	8.	25	2.8	Missing
N.A.	9.	866	96.2	Missing
	TOTAL	900	100.0	100.0

Most of the retention system failures noted in Table 9.5.2 were associated with severe forces applied to the retention system. For example, one helmeted rider was run over after the initial crash impact and the D-rings were pulled open as the helmet was snagged by the undercarriage of the automobile. In this case, the damage to the retention system occurred during or after the impact attenuation and the failure did not relate to helmet ejection and injury causation.

Premature failure of the retention system due to inadequate strength or defect was rare. Crazing of the polycarbonate shell at the rivet hole caused premature shell fracture and subsequent retention failure for that one helmet.

The requirements of retention strength and stiffness specified in DOT-FMVSS-218 appear to be adequate. There appears to be no need for higher or lower retention strength. Also, no accident cases showed helmet ejection due to some unusual impact dynamic problem which would require dynamic testing of the retention

system. The accident data show that a correctly fitting full or full facial coverage helmet which is securely fastened will be retained during crash impact.

Table 9.5.3 shows the crosstabulation of type of helmet coverage and fastening of the retention system. Riders wearing the full facial coverage helmet were the most lax about fastening the retention system. However, the retention effect of the greater coverage did prevent some of these unfastened helmets from being ejected at crash impact.

TABLE 9.5.3. RETENTION SYSTEM FASTENED BY TYPE OF HELMET COVERAGE (OSIDs)

Helmet Type	Count / Row Pct / Col Pct / Tot Pct	Retention System Fastened? Yes	No	Unknown	N.A.	Row Total
Partial		29	1	2	0	32
		90.6	3.1	6.3	0.0	3.6
		9.1	5.0	8.0	0.0	
		3.2	0.1	0.2	0.0	
Full		184	9	4	0	197
		93.4	4.6	2.0	0.0	21.9
		57.7	45.0	16.0	0.0	
		20.4	1.0	0.4	0.0	
Full Face 105°		12	2	0	0	14
		85.7	14.3	0.0	0.0	1.6
		3.8	10.0	0.0	0.0	
		1.3	0.2	0.0	0.0	
Full Face 120°		90	8	1	0	99
		90.9	8.1	1.0	0.0	11.0
		28.2	40.0	4.0	0.0	
		10.0	0.9	0.1	0.0	
Unknown		4	0	18	0	22
		18.2	0.0	81.8	0.0	2.4
		1.3	0.0	72.0	0.0	
		0.4	0.0	2.0	0.0	
N.A.		0	0	0	536	536
		0.0	0.0	0.0	100.0	59.6
		0.0	0.0	0.0	100.0	
		0.0	0.0	0.0	59.6	
	Column Total	319	20	25	536	900
		35.4	2.2	2.8	59.6	100.0

Table 9.5.4 shows a crosstabulation of type of helmet coverage and helmet retention. Comparison with Table 9.5.3 shows that the unfastened partial or full coverage helmet will make helmet ejection likely but the full facial coverage assists retention and fastening the retention system essentially insures retention.

TABLE 9.5.4. HELMET RETENTION PERFORMANCE BY TYPE OF HELMET COVERAGE (OSIDs)

Helmet Type	Count / Row Pct / Col Pct / Tot Pct	Helmet Retained?				Row Total
		Yes	No	Unknown	N.A.	
Partial		27 84.4 8.3 3.0	3 9.4 16.7 0.3	2 6.3 9.1 0.2	0 0.0 0.0 0.0	32 3.6
Full		187 94.9 57.7 20.8	9 4.6 50.0 1.0	1 0.5 4.5 0.1	0 0.0 0.0 0.0	197 21.9
Full Face 105°		12 85.7 3.7 1.3	2 14.3 11.1 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	14 1.6
Full Face 120°		94 94.9 29.0 10.4	4 4.0 22.2 0.4	1 1.0 4.5 0.1	0 0.0 0.0 0.0	99 11.0
Unknown		4 18.2 1.2 0.4	0 0.0 0.0 0.0	18 81.8 81.8 2.0	0 0.0 0.0 0.0	22 2.4
N.A.		0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	536 100.0 100.0 59.6	536 59.6
	Column Total	324 36.0	18 2.0	22 2.4	536 59.6	900 100.0

Table 9.5.5 shows the evaluation of the helmet fit and that evaluation indicated no difficulty for 84.1% of the accident-involved riders. Retention or injury problems were associated with helmets that were loose; crash impact would allow the helmet to slip and rotate causing ejection or injury due to interaction with eyeglasses.

Table 9.5.6 (Appendix C.5) provides a crosstabulation of helmet fit evaluation and ethnicity. There are no significant helmet fit problems shown related to ethnicity. However, it should be recalled that these are the accident-involved riders who were wearing helmets voluntarily.

TABLE 9.5.5. MOTORCYCLE RIDER HELMET FIT EVALUATION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Too Tight	1.	14	1.6	4.5	4.5
Correct	2.	260	28.9	84.1	88.7
Large	3.	30	3.3	9.7	98.4
Extra Loose	4.	3	0.3	1.0	99.4
Contour Problems	5.	2	0.2	0.6	100.0
Unknown	8.	58	6.4	Missing	100.0
N.A. No Helmet	9.	533	59.2	Missing	100.0
	TOTAL	900	100.0	100.0	

9.6 Safety Helmet Weight

Table 9.6.1 shows the weight of the safety helmet worn by the motorcycle riders in the 900 on-scene, in-depth accident cases. The median weight is approximately 2½ pounds and this represents the typical medium size full coverage safety helmet. Those three helmets weighing less than 1.75 lbs were not conventional motorcycle safety helmets but were lightweight equestrian or moped helmets generally unsuitable for traffic use.

TABLE 9.6.1. MOTORCYCLE RIDER HELMET WEIGHT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
<1.75	1.	3	0.3	1.2	1.2
1.75-1.99	2.	12	1.3	4.7	5.8
2.00-2.24	3.	24	2.7	9.3	15.2
2.25-2.49	4.	52	5.8	20.2	35.4
2.50-2.74	5.	61	6.8	23.7	59.1
2.75-2.99	6.	41	4.6	16.0	75.1
3.00-3.24	7.	35	3.9	13.6	88.7
>3.25	8.	29	3.2	11.3	100.0
Unknown	98.	106	11.8	Missing	100.0
N.A.	99.	537	59.7	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.6.2 shows a crosstabulation of the safety helmet type and weight. The general tendency shown is that the heavier helmets are those with full facial coverage. Since there are no appliances of significant weight, the higher weight helmets correspond to more shell and more liner for more complete coverage, and implied greater protection.

TABLE 9.6.2. HELMET WEIGHT BY HELMET TYPE (OSIDs)

Weight	Count Row Pct Col Pct Tot Pct	Helmet Type Partial	 Full	 Full Facial-105	 Full Facial-120	 Unknown	 N.A.	Row Total
< 1.75 lbs		3 100.0 9.4 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 0.3
1.75 to 1.99 lbs		8 66.7 25.0 0.9	4 33.3 2.0 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	12 1.3
2.00 to 2.24 lbs		6 25.0 18.8 0.7	17 70.8 8.6 1.9	0 0.0 0.0 0.0	1 4.2 1.0 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	24 2.7
2.25 to 2.49 lbs		3 5.8 9.4 0.3	46 88.5 23.4 5.1	0 0.0 0.0 0.0	3 5.8 3.0 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	52 5.8
2.50 to 2.74 lbs		2 3.3 6.3 0.2	40 65.6 20.3 4.4	0 0.0 0.0 0.0	19 31.1 19.2 2.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	61 6.8
2.75 to 2.99 lbs		0 0.0 0.0 0.0	23 56.1 11.7 2.6	1 2.4 7.1 0.1	17 41.5 17.2 1.9	0 0.0 0.0 0.0	0 0.0 0.0 0.0	41 4.6
3.00 to 3.24 lbs		0 0.0 0.0 0.0	12 34.3 6.1 1.3	2 5.7 14.3 0.2	21 60.0 21.2 2.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	35 3.9
3.25 and Over		0 0.0 0.0 0.0	2 6.9 1.0 0.2	8 27.6 57.1 0.9	19 65.5 19.2 2.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	29 3.2
Unknown		10 9.4 31.3 1.1	53 50.0 26.9 5.9	3 2.8 21.4 0.3	18 17.0 18.2 2.0	22 20.8 100.0 2.4	0 0.0 0.0 0.0	106 11.6
N.A.		0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.2 1.0 0.1	0 0.0 0.0 0.0	536 99.8 100.0 59.6	537 59.7
	Column Total	32 3.6	197 21.9	14 1.6	99 11.0	22 2.4	536 59.6	900 100.0

9.7 Safety Helmet Color

Table 9.7.1 shows the predominating color of the motorcycle rider safety helmet. White helmets predominate as 37.7% of the total. Helmet color is not expected to be a significant factor affecting conspicuity because the helmet surface presented to the other vehicle involved in collision is the (open) facial region. Because of the large open space required for vision, only a small part of the helmet surface is available to contribute to conspicuity. If conspicuity treatments were to be applied to the safety helmet, the effective treatments must be applied to the front of the helmet, visor and face shield without limiting required visual space.

TABLE 9.7.1. SAFETY HELMET COLOR (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
White	1.	125	13.9	37.7	37.7
Yellow	2.	11	1.2	3.3	41.0
Orange	3.	36	4.0	10.8	51.8
Black	4.	20	2.2	6.0	57.8
Brown	5.	13	1.4	3.9	61.7
Blue	6.	42	4.7	12.7	74.4
Red	7.	46	5.1	13.9	88.3
Purple	8.	3	0.3	0.9	89.2
Green	9.	5	0.6	1.5	90.7
Silver	10.	17	1.9	5.1	95.8
Grey	11.	3	0.3	0.9	96.7
Gold	12.	8	0.9	2.4	99.1
Metal Flake	13.	1	0.1	0.3	99.4
Other	14.	2	0.2	0.6	100.0
Unknown	98.	29	3.2	Missing	100.0
N.A.	99.	539	59.9	Missing	100.0
	TOTAL	900	100.0	100.0	

9.8 Safety Helmet Impact Analysis

The accident performance of a motorcycle safety helmet can be evaluated by detailed examination of that accident-involved helmet. Of course, the helmet must be available for the close and detailed examination and the helmet must be disassembled so that complete details of shell and liner damage are exposed. Most of the safety helmets involved in the 900 on-scene in-depth accident cases were acquired and retained by the research teams, primarily through the offer of replacement with a new helmet from SHCA membership. These acquired helmets were completely disassembled then inspected for evidence of shell and liner performance and those data recorded. In those cases where the helmet was not acquired, disassembly was done for a few helmets, external examination and photography was done for most helmets, but some helmets simply could not be examined. Interference and limitation by attorneys was encountered often. There are significant

differences in the techniques required for thorough examination of the helmet components. The signatures of impact on the helmet shell exterior differ with shell material and type of surface contacted. The signatures of impact on the liner surfaces differ with shell construction and liner material. Comparison of accident signatures with compliance test signatures and crash test signatures was vital to the identification of helmet performance.

The accident-involved helmet usually gave evidence of a variety of impacts, the majority of which were not life-threatening. The impacts were evaluated and only the two most severe impacts were coded for data purposes.

Table 9.8.1 shows the type of impact surface for the most severe impact to the motorcycle rider helmet. A flat surface predominates and represents 87.0% of all the most severe impacts to the safety helmet. The type of material of the impacting surface shows the expected contribution of pavement (71.6%) of the accident roadway and metal (21.8%) of the involved automobile or environment.

TABLE 9.8.1. TYPE OF IMPACT SURFACE FOR MOST SEVERE HELMET IMPACT (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Geometry of Struck Object-Rider				
Flat	1.	241	26.8	87.0
Blunt Edge	2.	15	1.7	5.4
Sharp Edge	3.	5	0.6	1.8
Blunt Object	4.	9	1.0	3.2
Sharp Object	5.	7	0.8	2.5
Unknown	8.	30	3.3	Missing
N.A., No Helmet or No Helmet Impact	9.	593	65.9	Missing
	TOTAL	900	100.0	100.0
Material of Object Struck-Rider				
Metal	1.	59	6.6	21.8
Glass	2.	7	0.8	2.6
Wood	3.	2	0.2	0.7
Soil	4.	7	0.8	2.6
Pavement	5.	194	21.6	71.6
Other	6.	2	0.2	0.7
Unknown	8.	36	4.0	Missing
N.A., No Helmet or No Helmet Impact	9.	593	65.9	Missing
	TOTAL	900	100.0	100.0

Table 9.8.2 shows the direction of impact for the first and second most severe impacts to the safety helmet. In this table, "Impact 1" is that most severe impact applied to the helmet and "Impact 2" is the second most severe impact applied to the helmet. If the impact occurred with a direct blow with

TABLE 9.8.2. IMPACT DIRECTIONS FOR MOST SEVERE HELMET IMPACTS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>Type of Impact, Impact 1-rider</u>				
Normal	1.	135	15.0	50.0
Tangential	2.	131	14.6	48.5
Crushing	3.	3	0.3	1.1
Other (Snagging)	7.	1	0.1	0.4
Unknown	8.	37	4.1	Missing
N.A.	9.	593	65.9	Missing
	TOTAL	900	100.0	100.0
<u>Type of Impact, Impact 2-rider</u>				
Normal	1.	65	7.2	40.4
Tangential	2.	92	10.2	57.1
Crushing	3.	4	0.4	2.5
Unknown	8.	38	4.2	Missing
N.A.	9.	701	77.9	Missing
	TOTAL	900	100.0	100.0

the greatest component perpendicular to the helmet surface, it was classified as a predominantly "normal" (or perpendicular impact). To be sure, such a normal impact has the prospect of transmitting the greatest threat to the head. If the impact occurred with a glancing blow with the greatest component tangential to the helmet surface, it was classified as predominantly "tangential" impact. In comparison to the predominantly normal impact, the predominantly tangential impact has the prospect of transmitting far less severe threat to the head. Table 9.8.2 shows that for the most severe "impact 1", the normal and tangential impacts have approximately equal contribution but it is clear that those normal impacts offer far greater threat. Crushing loads on the helmet were rare but involved severe forces such as impact between the motorcycle and the roadway or an automobile and the roadway. "Impact 2" shows less frequent impacts, and less frequent severe normal impacts.

Table 9.8.3 shows the number of discrete impacts on the motorcycle rider helmet at the two most severe impact sites. In most cases (91.1%), the most severe impact was a simple single critical impact at that location. A second - but far less severe - impact occurred at that general location in 6.3% of those same impact sites. There was <u>NO</u> case where a second impact of the same severity was superimposed on the original most severe impact site. As an example, the motorcycle rider collides with the automobile and strikes the left side of his helmeted head on the windshield and header then falls to the roadway, perhaps striking the back of his helmeted head on the roadway. The two impact sites are at different locations on the helmet, the impacts are with different surfaces, and the impacts are of different severity.

TABLE 9.8.3. NUMBER OF HELMET IMPACTS ON MOTORCYCLE RIDER HELMET (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Most Severe Impact					
	1.	245	27.2	91.1	91.1
	2.	17	1.9	6.3	97.4
	3.	5	0.6	1.9	99.3
	4.	2	0.2	0.7	100.0
Unknown	8.	38	4.2	Missing	100.0
N.A.	9.	593	65.9	Missing	100.0
	TOTAL	900	100.0	100.0	
Second Most Severe Impact					
	1.	143	15.9	88.8	88.8
	2.	18	2.0	11.2	100.0
Unknown	8.	38	4.2	Missing	100.0
N.A.	9.	701	77.9	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.8.4 shows the type of impact damage to the helmet shell at the two most severe impact sites. Of course, the more severe damage to the helmet shell is associated with the more severe impact conditions, relating the higher impact energy and greater requirement of energy absorption for impact attenuation. Delamination is a characteristic of fiberglass deformation and energy absorption, and is a measure of damage applicable only to fiberglass shell helmets. The helmet shell cracked, shattered and split at 1.8% of the most severe impact sites. In general, this extreme damage was related simply to the impact severity and the extreme impact forces. In a rare instance, shell fracture was related to defect and this was isolated to crazing and premature cracking of polycarbonate shell due to residual stress, e.g., crazing at retention system rivet holes.

Abrasion was the dominant damage to the shell at the two most severe impact sites, i.e., at least two-thirds of the shell damage recorded. In general, this abrasion was resisted well by the helmet shell and there were no injuries caused by any helmet failing to resist this abrasive loading. Puncture or penetration of the helmet shell was rare because such loads were resisted well. The usual result of helmet impact with a sharp edge was resistance to penetration and simply an abrasion at that location.

The impact sites on the safety helmets were located by descriptions of clock-face position from the top and left side of the helmet. For example, an impact site just above the right forehead would be located by 1 o'clock from the top and 10 o'clock from the left side. Table 9.8.5 shows the locations of the two most severe impacts to the motorcycle rider helmet with the locator as a clock-face position from a top view. Table 9.8.6 shows the locations of the two most severe impacts to the motorcycle rider helmet with the locator as a clock-face position from a left side view. Generally, those side locators in the clock-face positions of 4, 5, 6, 7, and 8 o'clock imply impacts on the helmet which are below the regions

TABLE 9.8.4. TYPE OF IMPACT DAMAGE TO RIDER HELMET SHELL (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>Most Severe Impact</u>				
None	0.	18	2.0	6.4
Abrasion	1.	193	21.4	68.9
Puncture	2.	2	0.2	0.7
Crack, Shatter, Split	3.	5	0.6	1.8
Delamination	5.	58	6.4	20.7
Fire	8.	1	0.1	0.4
Multiple	9.	1	0.1	0.4
Other	10.	2	0.2	0.7
Unknown	98.	35	3.9	Missing
N.A.	99.	585	65.0	Missing
	TOTAL	900	100.0	100.0
<u>Second Most Severe Impact</u>				
None	0.	15	1.7	8.7
Abrasion	1.	124	13.8	72.1
Crack, Shatter, Split	3.	4	0.4	2.3
Resin Fracture	4.	1	0.1	0.6
Delamination	5.	25	2.8	14.5
Other	10.	3	0.3	1.7
Unknown	98.	39	4.3	Missing
N.A.	99.	689	76.6	Missing
	TOTAL	900	100.0	100.0

of specified protection. From these data it is shown that this "below-the-belt" impact occurred in 11.5% of the most severe and 11.2% of the next most severe impacts.

Table 9.8.7 (Appendix C.5) provides a crosstabulation of locators for the rider most severe "impact 1". Table 9.8.8 (Appendix C.5) provides a crosstabulation of locators for the rider second most severe "impact 2".

Table 9.8.9 (Appendix C.5) provides a crosstabulation of locators for the passenger most severe "impact 1". Table 9.8.10 (Appendix C.5) provides a crosstabulation of locators for the passenger second most severe "impact 2".

Table 9.8.11 provides a crosstabulation of top and left side locators for the sum of all first and second most severe helmet impacts for both motorcycle riders and passengers. Table 9.8.12 illustrates the distribution of this sum of helmet impacts for the top and left side locators.

Before further consideration of these data on helmet impacts, it is important to note that these data represent only those impact sites on the helmet and do not include those impacts to the uncovered or unprotected areas of the head and

TABLE 9.8.5. IMPACT LOCATIONS ON THE MOTORCYCLE RIDER HELMET
MOST SEVERE IMPACTS - TOP VIEW (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Clock Position Top View-Most Severe Impact					
	1.	22	2.4	8.1	8.1
	2.	17	1.9	6.3	14.4
	3.	17	1.9	6.3	20.7
	4.	20	2.2	7.4	28.1
	5.	18	2.0	6.7	34.8
	6.	32	3.6	11.9	46.7
	7.	25	2.8	9.3	55.9
	8.	26	2.9	9.6	65.6
	9.	26	2.9	9.6	75.2
	10.	15	1.7	5.6	80.7
	11.	26	2.9	9.6	90.4
	12.	26	2.9	9.6	100.0
Unknown	98.	31	3.4	Missing	100.0
N.A.	99.	599	66.6	Missing	100.0
	TOTAL	900	100.0	100.0	
Clock Position Top View-Second Most Severe Impact					
	1.	9	1.0	5.6	5.6
	2.	7	0.8	4.3	9.9
	3.	12	1.3	7.5	17.4
	4.	12	1.3	7.5	24.8
	5.	11	1.2	6.8	31.7
	6.	24	2.7	14.9	46.6
	7.	16	1.8	9.9	56.5
	8.	15	1.7	9.3	65.8
	9.	13	1.4	8.1	73.9
	10.	13	1.4	8.1	82.0
	11.	13	1.4	8.1	90.1
	12.	16	1.8	9.9	100.0
Unknown	98.	36	4.0	Missing	100.0
N.A.	99.	703	78.1	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.8.6. IMPACT LOCATIONS ON MOTORCYCLE RIDER HELMET
MOST SEVERE IMPACTS - LEFT SIDE VIEW (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Clock Position Left Side View-Most Severe Impact	1.	40	4.4	14.8	14.8
	2.	37	4.1	13.7	28.4
	3.	43	4.8	15.9	44.3
	4.	14	1.6	5.2	49.4
	5.	1	0.1	0.4	49.8
	6.	2	0.2	0.7	50.6
	7.	4	0.4	1.5	52.0
	8.	10	1.1	3.7	55.7
	9.	7	0.8	2.6	58.3
	10.	52	5.8	19.2	77.5
	11.	33	3.7	12.2	89.7
	12.	28	3.1	10.3	100.0
Unknown	98.	35	3.9	Missing	100.0
N.A.	99.	594	66.0	Missing	100.0
	TOTAL	900	100.0	100.0	
Clock Position Left Side View-Second Most Severe Impact	1.	29	3.2	18.0	18.0
	2.	20	2.2	12.4	30.4
	3.	31	3.4	19.3	49.7
	4.	8	0.9	5.0	54.7
	6.	1	0.1	0.6	55.3
	7.	3	0.3	1.9	57.1
	8.	6	0.7	3.7	60.9
	9.	4	0.4	2.5	63.4
	10.	19	2.1	11.8	75.2
	11.	25	2.8	15.5	90.7
	12.	15	1.7	9.3	100.0
Unknown	98.	38	4.2	Missing	100.0
N.A.	99.	701	77.9	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.8.11. SUM OF ALL HELMET IMPACT SITES

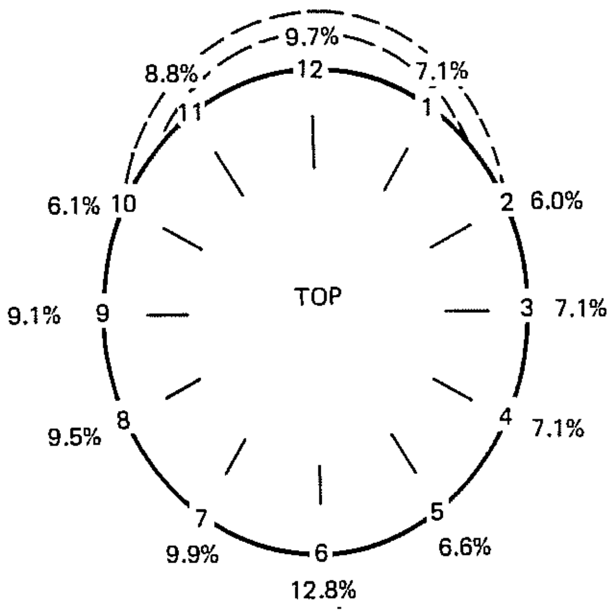
	Frequency	Top Clock Position Locator												Total (Percent)
		1	2	3	4	5	6	7	8	9	10	11	12	
Left Side Clock Position Locator	1	0	2	4	17	3	14	12	13	4	0	0	0	69 (15.2)
	2	0	1	1	8	9	11	8	14	6	1	1	0	60 (13.2)
	3	0	0	4	6	11	24	17	10	7	1	0	0	80 (17.7)
	4	0	0	0	1	5	3	7	4	0	0	0	1	21 (4.6)
	5	0	0	1	0	0	0	0	0	1	0	0	0	2 (0.4)
	6	0	0	2	0	0	0	0	0	1	0	0	0	3 (0.7)
	7	0	1	0	0	0	0	0	0	1	3	3	0	8 (1.8)
	8	5	0	0	0	0	1	0	0	0	0	5	5	16 (3.5)
	9	2	0	2	0	0	1	1	0	0	0	0	5	11 (2.4)
	10	15	9	0	0	2	2	0	0	1	8	20	19	76 (16.8)
	11	10	12	0	0	0	0	0	1	1	14	11	11	60 (13.2)
	12	0	2	18	0	0	2	0	1	19	2	0	3	47 (10.4)
	TOTAL (Percent)	32 (7.1)	27 (6.0)	32 (7.1)	32 (7.1)	30 (6.6)	58 (12.8)	45 (9.9)	43 (9.5)	41 (9.1)	29 (6.4)	40 (8.8)	44 (9.7)	453 (100.0)

neck. For example, impact sites shown with a left side locator of 7 or 8 o'clock clearly represent impacts on the chin piece of a full facial coverage helmet. Of course, many impacts occurred to the chin, jaw, teeth, cheek, mouth, etc. of those motorcycle riders who were wearing a partial or full coverage helmet, or were not wearing any helmet at all. In addition, a motorcycle rider could experience an impact low at the back of the head and have no helmet impact site recorded if no helmet were in use, or if a partial coverage helmet did not extend coverage to that area. These factors must be considered when evaluating the frequency of impacts to those areas which are generally below areas of specified protection.

In these data of Table 9.8.12, the impacts below areas of traditional specified coverage are approximately 13.4% of the total. This has implications regarding helmet qualification since impacts clearly occur in regions which are not required to provide protection. The regions of the face acquire exposure to impact because of visual space requirements but the back of the head has no such mandatory exposure. In this way, some impact protection and coverage needs to be specified for the back of the head below current requirements.

The distribution of all impacts shows a slight lack of symmetry with a higher frequency of impacts at the left rear of the helmets. The upper rear quadrant has 39.1% of the impacts; the upper front quadrant (including the side bands at 9 o'clock) has 38.1%; the left hemisphere has almost 10% more impacts than the right hemisphere (43.4% to 33.9%).

TABLE 9.8.12. SUMMARY OF ALL RIDER AND PASSENGER HELMET IMPACTS (OSIDs)



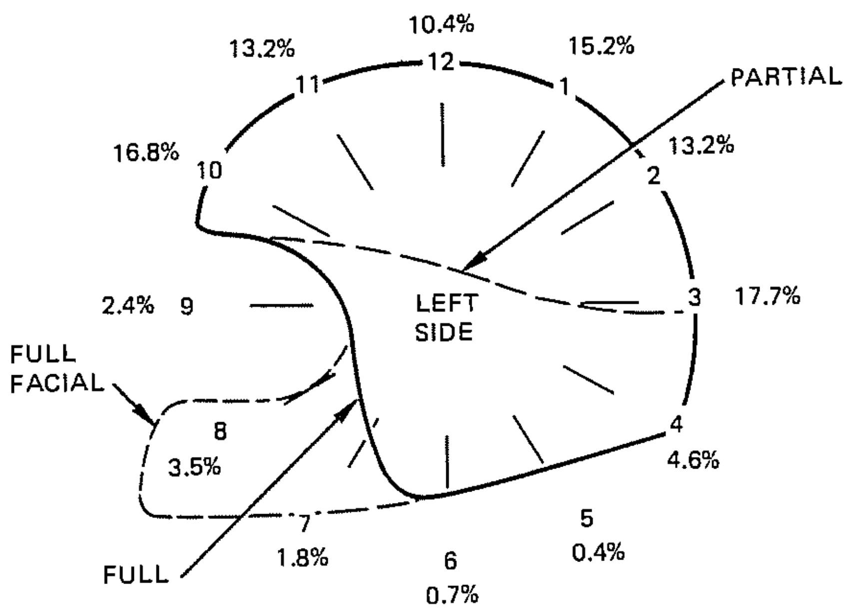


Table 9.8.13 (Appendix C.5) shows the measured liner crush, or compression permanent deformation, at the two most severe impact points on the motorcycle rider helmet. Because of the variation of recovery of the many different liner materials, it was difficult to relate this single measurement to impact severity. Only the styrofoam liner with low recovery gave consistent indications of impact severity.

The area of impact signature seemed to be the most reliable indicator of impact severity, since the area of liner compression could be distinguished for most all liner materials. The area measured and recorded was that area of liner loaded by impact to the shell and thereby flattened, softened, crushed, decorated, etc., so as to absorb the energy of the impact and attenuate the impact. Table 9.8.14 (Appendix C.5) shows the distribution of the impact signature areas for the two most severe impact sites for the motorcycle rider helmet. Combination of these two sets of signature areas gives the approximate cumulative frequencies:

Signature Area, $in.^2$	Cumulative Frequency, %
6.0	83.7
7.0	88.1
8.0	92.0
9.0	94.5

These specific points are of concern because the conventional flat anvil drop test height of 72 inches generally produces a liner decoration and signature area between 6 and 9 $in.^2$ for a single drop test. Of course, this signature area is variable with shell and liner construction, as well as location on the helmet. The important point is that the single test impact approximates the 90% level of impact severity, i.e., the single test impact is severe enough to exceed approximately 90% of the accident impacts.

9.9 Safety Helmet Effectiveness: Head and Neck Injury Type of Lesion

Table 9.9.1 shows the type of lesion for the 861 discrete head and neck injuries experienced by the motorcycle riders in the 900 on-scene, in-depth accident cases. Recall from previous data that 39.4% of these riders were using some type of safety helmet. The overall effect of helmet use is powerful with the helmeted riders experiencing only 22.8% of all head and neck injuries. The helmeted riders show significantly lower injury frequency in all types of lesions.

Of course, there are limits to the effectiveness of safety helmets, and it is not possible to eliminate head and neck injury by safety helmet use. First, it should be obvious that a safety helmet can not protect areas of the head and neck which are not covered. For example, the simplest function of the safety helmet is to provide the smooth, hard surface to prevent abrasion. According to those data of Table 9.9.1, that function was well done with the helmeted riders experiencing 17.7% of the abrasion. However, if the motorcycle rider is using a partial or full coverage helmet and slides face down on the pavement, facial abrasions are likely to occur on those unprotected regions. In the same circumstances, the use of the full facial coverage helmet would provide the more complete coverage and

TABLE 9.9.1. RIDER HEAD AND NECK INJURY LESION TYPE BY HELMET USE

Count Row Pct Col Pct Tot Pct	Abrasion	Burn	Contusion	Dislocation	Fracture	Swelling	Hemorrhage	Hematoma	Concussion	Laceration	Row Total
With Helmet	28 14.3 17.7 3.3	1 0.5 50.0 0.1	12 6.1 14.3 1.4	1 0.5 50.0 0.1	32 16.3 23.7 3.7	0 0.0 0.0 0.0	10 5.1 26.3 1.2	9 4.6 20.5 1.0	27 13.8 30.3 3.1	50 25.5 24.3 5.8	196 22.8
Without Helmet	130 19.6 82.3 15.1	1 0.2 50.0 0.1	71 10.7 84.5 8.2	1 0.2 50.0 0.1	102 15.4 75.6 11.8	4 0.6 100.0 0.5	28 4.2 73.7 3.3	35 5.3 79.5 4.1	62 9.4 69.7 7.2	156 23.5 75.7 18.1	663 77.0
Unknown	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 1.2 0.1	0 0.0 0.0 0.0	1 50.0 0.7 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
Column Total	158 18.4	2 0.2	84 9.8	2 0.2	135 15.7	4 0.5	38 4.4	44 5.1	89 10.3	206 23.9	861 100.0

Count Row Pct Col Pct Tot Pct	Amputation	Crushing	Other	Pain	Maceration	Rupture	Sprain	Herniation	Unknown	Avulsion	Row Total
With Helmet	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.5 100.0 0.1	21 10.7 34.4 2.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 1.0 20.0 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 1.0 16.7 0.2	196 22.8
Without Helmet	2 0.3 100.0 0.2	3 0.5 100.0 0.3	0 0.0 0.0 0.0	40 6.0 65.6 4.6	4 0.6 100.0 0.5	4 0.6 100.0 0.5	8 1.2 80.0 0.9	1 0.2 100.0 0.1	1 0.2 100.0 0.1	10 1.5 83.3 1.2	663 77.0
Unknown	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
Column Total	2 0.2	3 0.3	1 0.1	61 7.1	4 0.5	4 0.5	10 1.2	1 0.1	1 0.1	12 1.4	861 100.0

eliminate such facial abrasions. Essentially the same situation is true for all of the other lesions of high frequency, i.e., contusion, fracture, hemorrhage, hematoma, concussion, laceration and avulsion. An exception was pain, which was a diffused, non-specific complaint typical of all accident-involved motorcycle riders.

Because of the frontal orientation of the motorcycle crash impact, there is the threat of facial impact and many facial injuries were experienced by both unhelmeted and helmeted riders. In this regard, the expectation of facial injury in the motorcycle accident would be essentially the same for helmeted and unhelmeted riders, unless the helmet was full facial coverage thereby offering some protection to the facial regions.

Another factor related to helmet coverage is a comparison of the partial and full coverage helmets. The partial coverage helmet leaves a large area of the temporal and occipital regions exposed without coverage. Impacts do occur in these areas, and injuries result where there is no coverage and no protection. There is no adverse effect regarding hearing, surely no relation to the visual field, and a definite advantage of protection by including that additional coverage offered by the full coverage helmet.

A final limit to the effectiveness of the safety helmets in these accident data is the extreme severity of the motorcycle accidents. Consider some of the following most severe motorcycle accidents investigated in this research:

(1) Rider face-first into a power pole at 34 mph.

(2) Rider run-over, snagged and dragged underneath an automobile on the freeway.

(3) Rider crushed between tumbling 700 lb. motorcycle and concrete curb.

(4) Rider head first into a concrete curb at 28 mph.

(5) Rider head first into an automobile windshield at a relative speed of 40 mph.

(6) Rider head first into posts and Armco barrier at 44 mph.

(7) Rider frontal impact on side of VW at 38 mph.

These extreme conditions present a formidable problem for head protection and the expectations of survival must have physical and practical limitations. However, contemporary helmets often provide spectacular results, i.e., incredibly, cases 2, 4, and 5 involved helmeted riders who survived those severe accident circumstances with only minor head and neck injuries.

These data show a special advantage to the motorcycle rider wearing a safety helmet. The helmet reduces or prevents most of the injury to protected regions, but does not exclude injury to unprotected regions or injury in very severe accident configurations.

Table 9.9.2 shows the type of lesion for the 136 discrete head and neck injuries experienced by the passengers in the 900 on-scene, in-depth accident cases. Recall from previous data that 15.9% of these passengers were using some type of safety helmet. The overall effect of helmet use is powerful, with the helmeted passengers experiencing only 9.6% of all head and neck injuries. These helmeted passengers show significantly lower injury frequency in all types of lesions.

TABLE 9.9.2. PASSENGER HEAD AND NECK INJURY LESION TYPE BY HELMET USE (OSIDs)

Count Row Pct Col Pct Tot Pct	Abrasion	Contusion	Fracture	Hemorrhage	Hematoma	Concussion	Laceration	Pain	Sprain	Avulsion	Row Total
With Helmet	4 30.8 14.8 2.9	1 7.7 5.0 0.7	1 7.7 5.9 0.7	1 7.7 12.5 0.7	0 0.0 0.0 0.0	3 23.1 16.7 2.2	2 15.4 8.0 1.5	1 7.7 9.1 0.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	13 9.6
Without Helmet	23 18.7 85.2 16.9	19 15.4 95.0 14.0	16 13.0 94.1 11.8	7 5.7 87.5 5.1	8 6.5 100.0 5.9	15 12.2 83.3 11.0	23 18.7 92.0 16.9	10 8.1 90.9 7.4	1 0.8 100.0 0.7	1 0.8 100.0 0.7	123 90.4
Column Total	27 19.9	20 14.7	17 12.5	8 5.9	8 5.9	18 13.2	25 18.4	11 8.1	1 0.7	1 0.7	136 100.0

As with the motorcycle rider head and neck injury analysis, helmet coverage essentially excluded injury to protected regions. The head and neck injuries experienced by helmeted passengers were injuries to unprotected regions or occurred in accident configurations of extreme severity.

9.10 Safety Helmet Effectiveness: Head and Neck Injury Severity

Table 9.10.1 shows the severity of the 861 discrete head and neck injuries experienced by the motorcycle riders in the 900 on-scene, in-depth accident cases. Recall that 39.4% of these riders were using some type of safety helmet. These data show that the helmeted riders have significantly lower injury frequency at all levels of injury severity.

TABLE 9.10.1. RIDER HEAD AND NECK INJURY SEVERITY BY HELMET USE (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
With Helmet	134 68.4 23.4 15.6	27 13.8 24.1 3.1	12 6.1 16.2 1.4	7 3.6 23.3 0.8	10 5.1 20.4 1.2	6 3.1 26.1 0.7	0 0.0 0.0 0.0	196 22.8
Without Helmet	437 65.9 76.4 50.8	84 12.7 75.0 9.8	62 9.4 83.8 7.2	23 3.5 76.7 2.7	39 5.9 79.6 4.5	17 2.6 73.9 2.0	1 0.2 100.0 0.1	663 77.0
Unknown	1 50.0 0.2 0.1	1 50.0 0.9 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
Column Total	572 66.4	112 13.0	74 8.6	30 3.5	49 5.7	23 2.7	1 0.1	861 100.0

Table 9.10.2 shows the severity of the 136 discrete head and neck injuries experienced by the passengers in the 900 on-scene, in-depth accident cases. Recall that 15.9% of these passengers were using some type of safety helmet. These data show that the helmeted passengers have significantly lower injury frequency at all levels of injury severity.

9.11 Safety Helmet Effectiveness: Overall Severities Sum (SS) and Head and Neck Severities Sum (SS2)

Table 9.11.1 (Appendix C.5) shows the overall Severities Sum (SS)* for the motorcycle riders in the 900 on-scene, in-depth accident cases. These overall Severities Sums are obtained from the addition of the somatic severities sum (SS1) and the head and neck severities sum (SS2). The overall severities sum is cross-tabulated with the type of helmet coverage.

*N.B. All "Severities Sums" are in fact sums of the individual injury severities squared.

TABLE 9.10.2. PASSENGER HEAD AND NECK INJURY SEVERITY BY HELMET USE (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Row Total
With Helmet	11 84.6 11.3 8.1	1 7.7 8.3 0.7	1 7.7 7.7 0.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	13 9.6
Without Helmet	86 69.9 88.7 63.2	11 8.9 91.7 8.1	12 9.8 92.3 8.8	1 0.8 100.0 0.7	13 10.6 100.0 9.6	123 90.4
Column Total	97 71.3	12 8.8	13 9.6	1 0.7	13 9.6	136 100.0

Table 9.11.2 (Appendix C.5) shows the head and neck severities sum (SS2) crosstabulated with the type of helmet coverage.

Table 9.11.3 (Appendix C.5) provides the head and neck severities sum (SS2) for the 54 fatal accidents for comparison. The fatally injured motorcycle riders wearing helmets are approximately one-fourth of the fatalities at all levels of head and neck severities sum (SS2).

The data of Table 9.11.1 do not distinguish the advantages of helmet use as concisely as do the data of Table 9.11.2. When the data of Table 9.11.2 are summarized, there is a special measure of helmet effectiveness, and these results are shown in Table 9.11.4.

The effectiveness of helmets in the 900 cases of on-scene, in-depth investigations is illustrated by the criterion of <u>NO</u> head and neck injury, i.e., SS2 = 0. Table 9.11.4(A) shows the data for the helmeted and unhelmeted riders with NO head and neck injury. The significance of these data is extremely high and shows that a very high level of head and neck protection from <u>all</u> injuries is afforded to those helmeted motorcycle riders.

Table 9.11.4(B) utilizes the criterion of head and neck injuries which exceed the severities sum of 10, i.e., SS2 $\geq$ 10. For purposes of comparison, a cerebral concussion which causes unconsciousness for a period of one hour would have AIS = 3 or SS2 = 9. The boundary of SS2 = 10 represents the fact that helmeted riders receive a high level of head and neck protection from <u>severe</u> injuries.

Table 9.11.4(C) utilizes the criterion of head and neck injuries which exceed the severities sum of 25, i.e., SS2 $\geq$ 25. For purposes of comparison, a temporal bone skull fracture with hemorrhage would have AIS = 5, or SS2 = 25.

TABLE 9.11.4. HELMET EFFECTIVENESS AT VARIOUS LEVELS OF HEAD AND NECK SEVERITY SUM, SS2 (OSIDs)

A) At the level of SS2 = 0

	SS2 = 0	SS2 > 0	TOTAL
Helmet	245	97	342
No Helmet	247	284	536
TOTAL	492	386	878

(χ^2 = 54.3)

B) At the level of SS2 = 10

	SS2 < 10	SS2 $\geq$ 10	TOTAL
Helmet	325	17	342
No Helmet	473	63	536
TOTAL	798	80	878

(χ^2 = 10.8)

C) At the level of SS2 = 25

	SS2 < 25	SS2 $\geq$ 25	TOTAL
Helmet	330	12	342
No Helmet	492	44	536
TOTAL	822	56	878

(χ^2 = 6.96)

D) At the level of SS2 = 50

	SS2 < 50	SS2 $\geq$ 50	TOTAL
Helmet	337	5	342
No Helmet	571	25	536
TOTAL	848	30	878

(χ^2 = 5.55)

This boundary of SS2 = 25 represents the border of critical, probably severe impairment, and possibly fatal head and neck injury. The data of Table 9.11.4(C) are significant and represent the fact that helmeted riders receive a high level of head and neck protection from critical and possibly fatal injuries.

Table 9.11.4(D) utilizes the criterion of head and neck injuries which exceed the severities sum of 50, i.e., SS2 $\geq$ 50. For purposes of comparison, this severities sum represents a clearly fatal head and neck injury. The data of Table 9.11.4(D) are significant and represent the fact that helmeted riders receive a high level of head and neck protection from clearly fatal injuries.

These summaries of data in Table 9.11.4 depict the entire spectrum of advantage for safety helmet use. It is clear that the safety helmets provide significant protection at all levels of head and neck injury severity.

Unfortunately, these data do not distinguish the special effects of helmet type or helmet coverage. The partial, full, and full facial coverage helmets participate at all levels of head and neck injury severity with approximately the same distribution.

9.12 Safety Helmet Effectiveness: Head and Neck Injury Region

Table 9.12.1 shows the 195 discrete head and neck injuries identified with the helmeted riders in the 900 on-scene, in-depth accident cases. Table 9.12.2 shows the 663 discrete head and neck injuries identified with the unhelmeted riders in that same group of 900 accident cases.

These data confirm expected differences in injury region and severity between the helmeted and unhelmeted riders. The typical regions of helmet coverage would lead to expectations of relatively lower injury frequencies in the following regions:

Frontal (10.3% vs. 14.9%)

Orbit (3.6% vs. 6.0%)

Occipital (3.1% vs. 6.8%)

Parietal (2.6% vs. 8.4%)

Temporal (2.6% vs. 5.9%)

Also, these data confirm expected similarities in injury region and severity since the eyespace opening in any helmet allows exposure to the following areas:

Nasal (5.6% vs. 5.6%)

Maxilla (4.1% vs. 4.8%)

Zygoma (6.7% vs. 4.5%)

Tables 9.12.3 and 9.12.4 show the equivalent crosstabulations of head and neck injury region and severity for the helmeted and unhelmeted passengers. The limited frequency of helmeted passenger injuries to the head and neck regions does not provide an equivalent comparison for helmet benefit to particular areas. However, there is favorable comparison between unhelmeted passengers and unhelmeted riders, with the unprotected areas suffering high exposure and high injury frequency.

TABLE 9.12.1. RIDER HEAD AND NECK INJURY SEVERITY BY INJURY REGION: HELMETED RIDERS (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
B Basal	0 0.0 0.0 0.0	0 0.0 0.0 0.0	6 46.2 50.0 3.1	2 15.4 28.6 1.0	3 23.1 33.3 1.5	2 15.4 33.3 1.0	13 6.7
C Cervical-General	24 92.3 17.9 12.3	1 3.8 3.7 0.5	1 3.8 8.3 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	26 13.3
F Frontal	18 90.0 13.4 9.2	1 5.0 3.7 0.5	0 0.0 0.0 0.0	1 5.0 14.3 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	20 10.3
K Face-General	8 88.9 6.0 4.1	1 11.1 3.7 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	9 4.6
M Mandible	26 83.9 19.4 13.3	5 16.1 18.5 2.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	31 15.9
N Nasal	9 81.8 6.7 4.6	2 18.2 7.4 1.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	11 5.6
O Occipital	3 50.0 2.2 1.5	0 0.0 0.0 0.0	2 33.3 16.7 1.0	0 0.0 0.0 0.0	1 16.7 11.1 0.5	0 0.0 0.0 0.0	6 3.1
P Parietal	2 40.0 1.5 1.0	1 20.0 3.7 0.5	0 0.0 0.0 0.0	1 20.0 14.3 0.5	0 0.0 0.0 0.0	1 20.0 16.7 0.5	5 2.6
Q Brain-General	12 37.5 9.0 6.2	11 34.4 40.7 5.6	2 6.3 16.7 1.0	1 3.1 14.3 0.5	5 15.6 55.6 2.6	1 3.1 16.7 0.5	32 16.4
R Orbit	7 100.0 5.2 3.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	7 3.6
Column Total	134 68.7	27 13.8	12 6.2	7 3.6	9 4.6	6 3.1	195 100.0

Continued

TABLE 9.12.1 (continued)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
S Sphenoid	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 14.3 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.5
T Temporal	5 100.0 3.7 2.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 2.6
W Whole Region	1 100.0 0.7 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.5
X Maxilla	7 87.5 5.2 3.6	1 12.5 3.7 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	8 4.1
Y Throat	1 33.3 0.7 0.5	1 33.3 3.7 0.5	0 0.0 0.0 0.0	1 33.3 14.3 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 1.5
Z Zygoma	10 76.9 7.5 5.1	3 23.1 11.1 1.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	13 6.7
1 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 33.3 1.0	2 1.0
2 Cervical Vertebra	1 100.0 0.7 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.5
7 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 8.3 0.5	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.5
Column Total	134 68.7	27 13.8	12 6.2	7 3.6	9 4.6	6 3.1	195 100.0

TABLE 9.12.2. RIDER HEAD AND NECK INJURY SEVERITY BY INJURY REGION: UNHELMETED RIDERS (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
B Basal	0	0	16	4	5	1	0	26
	0.0	0.0	61.5	15.4	19.2	3.8	0.0	3.9
	0.0	0.0	25.8	17.4	12.8	5.9	0.0	
	0.0	0.0	2.4	0.6	0.8	0.2	0.0	
C Cervical-General	49	1	1	0	2	2	0	55
	89.1	1.8	1.8	0.0	3.6	3.6	0.0	8.3
	11.2	1.2	1.6	0.0	5.1	11.8	0.0	
	7.4	0.2	0.2	0.0	0.3	0.3	0.0	
F Frontal	84	4	0	4	3	4	0	99
	84.8	4.0	0.0	4.0	3.0	4.0	0.0	14.9
	19.2	4.8	0.0	17.4	7.7	23.5	0.0	
	12.7	0.6	0.0	0.6	0.5	0.6	0.0	
H Foramen Magnum	0	0	0	0	0	1	0	1
	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.2
	0.0	0.0	0.0	0.0	0.0	5.9	0.0	
	0.0	0.0	0.0	0.0	0.0	0.2	0.0	
K Face-General	38	1	0	0	0	0	0	39
	97.4	2.6	0.0	0.0	0.0	0.0	0.0	5.9
	8.7	1.2	0.0	0.0	0.0	0.0	0.0	
	5.7	0.2	0.0	0.0	0.0	0.0	0.0	
M Mandible	52	12	4	0	0	0	0	68
	76.5	17.6	5.9	0.0	0.0	0.0	0.0	10.3
	11.9	14.3	6.5	0.0	0.0	0.0	0.0	
	7.8	1.8	0.6	0.0	0.0	0.0	0.0	
N Nasal	31	6	0	0	0	0	0	37
	83.8	16.2	0.0	0.0	0.0	0.0	0.0	5.6
	7.1	7.1	0.0	0.0	0.0	0.0	0.0	
	4.7	0.9	0.0	0.0	0.0	0.0	0.0	
O Occipital	25	5	7	1	7	0	0	45
	55.6	11.1	15.6	2.2	15.6	0.0	0.0	6.8
	5.7	6.0	11.3	4.3	17.9	0.0	0.0	
	3.8	0.8	1.1	0.2	1.1	0.0	0.0	
P Parietal	25	13	8	4	5	1	0	56
	44.6	23.2	14.3	7.1	8.9	1.8	0.0	8.4
	5.7	15.5	12.9	17.4	12.8	5.9	0.0	
	3.8	2.0	1.2	0.6	0.8	0.2	0.0	
Q Brain-General	19	24	10	3	12	3	0	71
	26.8	33.8	14.1	4.2	16.9	4.2	0.0	10.7
	4.3	28.6	16.1	13.0	30.8	17.6	0.0	
	2.9	3.6	1.5	0.5	1.8	0.5	0.0	
R Orbit	32	3	5	0	0	0	0	40
	80.0	7.5	12.5	0.0	0.0	0.0	0.0	6.0
	7.3	3.6	8.1	0.0	0.0	0.0	0.0	
	4.8	0.5	0.8	0.0	0.0	0.0	0.0	
Column Total	437 65.9	84 12.7	62 9.4	23 3.5	39 5.9	17 2.6	1 0.2	663 100.0

Continued

TABLE 9.12.1 (continued)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Unknown 8	Row Total
T Temporal	22 56.4 5.0 3.3	5 12.8 6.0 0.8	4 10.3 6.5 0.6	4 10.3 17.4 0.6	3 7.7 7.7 0.5	1 2.6 5.9 0.2	0 0.0 0.0 0.0	39 5.9
U Unknown	4 50.0 0.9 0.6	1 12.5 1.2 0.2	0 0.0 0.0 0.0	2 25.0 8.7 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 12.5 100.0 0.2	8 1.2
W Whole Region	1 33.3 0.2 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 33.3 4.3 0.2	0 0.0 0.0 0.0	1 33.3 5.9 0.2	0 0.0 0.0 0.0	3 0.5
X Maxilla	25 78.1 5.7 3.8	7 21.9 8.3 1.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	32 4.8
Y Throat	1 33.3 0.2 0.2	1 33.3 1.2 0.2	1 33.3 1.6 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 0.5
Z Zygoma	29 96.7 6.6 4.4	1 3.3 1.2 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	30 4.5
1 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 16.7 1.6 0.2	0 0.0 0.0 0.0	2 33.3 5.1 0.3	3 50.0 17.6 0.5	0 0.0 0.0 0.0	6 0.9
2 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 1.6 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.2
5 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 3.2 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.3
6 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 3.2 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.3
Column Total	437 65.9	84 12.7	62 9.4	23 3.5	39 5.9	17 2.6	1 0.2	663 100.0

TABLE 9.12.3. PASSENGER HEAD AND NECK INJURY SEVERITY BY INJURY REGION: HELMETED PASSENGERS (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Row Total
C Cervical-General	1 100.0 9.1 7.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 7.7
F Frontal	1 100.0 9.1 7.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 7.7
K Face-General	1 100.0 9.1 7.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 7.7
M Mandible	3 100.0 27.3 23.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 23.1
N Nasal	2 100.0 18.2 15.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 15.4
P Parietal	1 100.0 9.1 7.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 7.7
Q Brain-General	1 33.3 9.1 7.7	1 33.3 100.0 7.7	1 33.3 100.0 7.7	3 23.1
R Orbit	1 100.0 9.1 7.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 7.7
Column Total	11 84.6	1 7.7	1 7.7	13 100.0

TABLE 9.12.4. PASSENGER HEAD AND NECK INJURY SEVERITY BY INJURY REGION: UNHELMETED PASSENGERS (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Row Total
B	0	0	6	0	1	7
Basal	0.0	0.0	85.7	0.0	14.3	5.7
	0.0	0.0	50.0	0.0	7.7	
	0.0	0.0	4.9	0.0	0.8	
C	9	0	0	0	0	9
Cervical-General	100.0	0.0	0.0	0.0	0.0	7.3
	10.5	0.0	0.0	0.0	0.0	
	7.3	0.0	0.0	0.0	0.0	
F	19	0	0	0	1	20
Frontal	95.0	0.0	0.0	0.0	5.0	16.3
	22.1	0.0	0.0	0.0	7.7	
	15.4	0.0	0.0	0.0	0.8	
K	6	0	0	0	0	6
Face-General	100.0	0.0	0.0	0.0	0.0	4.9
	7.0	0.0	0.0	0.0	0.0	
	4.9	0.0	0.0	0.0	0.0	
M	6	0	0	0	0	6
Mandible	100.0	0.0	0.0	0.0	0.0	4.9
	7.0	0.0	0.0	0.0	0.0	
	4.9	0.0	0.0	0.0	0.0	
N	3	1	0	0	0	4
Nasal	75.0	25.0	0.0	0.0	0.0	3.3
	3.5	9.1	0.0	0.0	0.0	
	2.4	0.8	0.0	0.0	0.0	
O	9	2	3	0	1	15
Occipital	60.0	13.3	20.0	0.0	6.7	12.2
	10.5	18.2	25.0	0.0	7.7	
	7.3	1.6	2.4	0.0	0.8	
P	7	1	0	0	1	9
Parietal	77.8	11.1	0.0	0.0	11.1	7.3
	8.1	9.1	0.0	0.0	7.7	
	5.7	0.8	0.0	0.0	0.8	
Q	6	6	2	1	9	24
Brain-General	25.0	25.0	8.3	4.2	37.5	19.5
	7.0	54.5	16.7	100.0	69.2	
	4.9	4.9	1.6	0.8	7.3	
R	9	0	1	0	0	10
Orbit	90.0	0.0	10.0	0.0	0.0	8.1
	10.5	0.0	8.3	0.0	0.0	
	7.3	0.0	0.8	0.0	0.0	
T	2	0	0	0	0	2
Temporal	100.0	0.0	0.0	0.0	0.0	1.6
	2.3	0.0	0.0	0.0	0.0	
	1.6	0.0	0.0	0.0	0.0	
U	3	0	0	0	0	3
Unknown	100.0	0.0	0.0	0.0	0.0	2.4
	3.5	0.0	0.0	0.0	0.0	
	2.4	0.0	0.0	0.0	0.0	
X	4	0	0	0	0	4
Maxilla	100.0	0.0	0.0	0.0	0.0	3.3
	4.7	0.0	0.0	0.0	0.0	
	3.3	0.0	0.0	0.0	0.0	
Z	3	1	0	0	0	4
Zygoma	75.0	25.0	0.0	0.0	0.0	3.3
	3.5	9.1	0.0	0.0	0.0	
	2.4	0.8	0.0	0.0	0.0	
Column	86	11	12	1	13	123
Total	69.9	8.9	9.8	0.8	10.6	100.0

9.13 Safety Helmet Effectiveness: Neck Only Injury Severity

Table 9.13.1a shows the crosstabulation of neck only injury severity and helmet use for the 102 neck injuries experienced by the motorcycle riders in the 900 on-scene, in-depth accident cases. The motorcycle riders wearing helmets were 39.8% of the accident-involved riders but these riders accounted for less than their share of neck injuries, 32.4%. This distribution of neck injuries does not provide statistical significance of this favorable effect but it is clear that there is no liability for helmet use. These data simply confirm that there is no world-shaking advantage or disadvantage of motorcycle helmet use in relation to neck injury.

Table 9.13.1b shows the very limited data on neck only injury severity and helmet use for the accident-involved passengers. Of course, these sparse data do not confirm advantage or disadvantage to helmet use related to neck injury.

Neck injury for motorcycle riders (and passengers) seems to be closely associated with head impact. For example, the motorcycle accident victim often falls headfirst to the roadway, making contact with the left shoulder and left side of the head. The impact of the left side of the head can cause lateral flexion or extension displacement of the neck with the prospect of related neck injury. In this situation, there are competing factors when a safety helmet is involved. Any safety helmet which attenuates head impact and reduces the linear acceleration response of the head would also reduce rotational acceleration response of the head and the extension-flexion response of the neck. On the other hand, the weight of the helmet on the head would tend to increase inertial and post-impact response of the head and neck.

The net effect does not appear to strongly favor either of these competing factors and there is no significant contribution of the helmet use in neck injury.

Another important factor bearing on this proposition is that those impacts which occur to the unprotected face can transmit force to the head and the neck independent of helmet use. Consider the following example: The motorcycle rider wearing a full coverage helmet impacts his unprotected face on the A-pillar of the automobile involved in the collision. The facial impact transmits deadly force through the facial bones to the cranium without significant attenuation. Thus severe brain injury is possible, hyperextension of the neck is likely, and dislocation-fracture of the upper cervical spine is possible. In those instances of severe impact to the mandible, the transmitted force can generate fractures at the base of the skull with deadly consequences. In any such case, helmet use is completely unrelated to the head and neck injuries.

In the event of impact to the front of a full facial coverage helmet, energy absorbing material inside the shell of the chin piece will reduce the energy transmitted to the facial bones, skull and brain. The resulting loading of the neck in hyperextension is a critical source for neck injury, and the greater impact attenuation will reduce neck motions.

TABLE 9.13.1. NECK (ONLY) INJURY SEVERITY BY HELMET USE

a. Riders

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
With Helmet	26 78.8 34.2 25.5	2 6.1 50.0 2.0	2 6.1 20.0 2.0	1 3.0 100.0 1.0	0 0.0 0.0 0.0	2 6.1 28.6 2.0	33 32.4
Without Helmet	50 72.5 65.8 49.0	2 2.9 50.0 2.0	8 11.6 80.0 7.8	0 0.0 0.0 0.0	4 5.8 100.0 3.9	5 7.2 71.4 4.9	69 67.6
Column Total	76 74.5	4 3.9	10 9.8	1 1.0	4 3.9	7 6.9	102 100.0

b. Passengers

Count Row Pct Col Pct Tot Pct	Minor 1	Row Total
With Helmet	1 100.0 10.0 10.0	1 10.0
Without Helmet	9 100.0 90.0 90.0	9 90.0
Column Total	10 100.0	10 100.0

9.14 Effect of Helmet Coverage on Motorcycle Rider Most Severe Head Injury

There were 287 cases among the 900 on-scene, in-depth accident investigation where the motorcycle rider experienced injuries to the head. In this analysis the region of the head excludes the face and considers only these regions which would be covered and protected by a contemporary configuration of helmet. Essentially these regions are the cranium and enclosed brain. Table 9.14.1 shows a crosstabulation of the most severe head injury region with injury severity for those 287 cases. Note that several injuries could be present in each of these cases, but only the most severe is depicted in Table 9.14.1.

TABLE 9.14.1. RIDER MOST SEVERE HEAD INJURY: INJURY SEVERITY BY INJURY REGION (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
B	0	0	5	1	3	3	12
Basal	0.0	0.0	41.7	8.3	25.0	25.0	4.2
	0.0	0.0	25.0	11.1	10.0	21.4	
	0.0	0.0	1.7	0.3	1.0	1.0	
F	67	2	0	1	2	4	76
Frontal	88.2	2.6	0.0	1.3	2.6	5.3	26.5
	39.9	4.3	0.0	11.1	6.7	28.6	
	23.3	0.7	0.0	0.3	0.7	1.4	
H	0	0	0	0	0	1	1
Foramen Magnum	0.0	0.0	0.0	0.0	0.0	100.0	0.3
	0.0	0.0	0.0	0.0	0.0	7.1	
	0.0	0.0	0.0	0.0	0.0	0.3	
O	20	3	1	1	2	0	27
Occipital	74.1	11.1	3.7	3.7	7.4	0.0	9.4
	11.9	6.5	5.0	11.1	6.7	0.0	
	7.0	1.0	0.3	0.3	0.7	0.0	
P	21	6	2	1	5	2	37
Parietal	56.8	16.2	5.4	2.7	13.5	5.4	12.9
	12.5	13.0	10.0	11.1	16.7	14.3	
	7.3	2.1	0.7	0.3	1.7	0.7	
Q	21	31	9	4	16	3	84
Brain-General	25.0	36.9	10.7	4.8	19.0	3.6	29.3
	12.5	67.4	45.0	44.4	53.3	21.4	
	7.3	10.8	3.1	1.4	5.6	1.0	
R	23	3	3	0	0	0	29
Orbit	79.3	10.3	10.3	0.0	0.0	0.0	10.1
	13.7	6.5	15.0	0.0	0.0	0.0	
	8.0	1.0	1.0	0.0	0.0	0.0	
T	16	1	0	1	2	1	21
Temporal	76.2	4.8	0.0	4.8	9.5	4.8	7.3
	9.5	2.2	0.0	11.1	6.7	7.1	
	5.6	0.3	0.0	0.3	0.7	0.3	
Column	168	46	20	9	30	14	287
Total	58.5	16.0	7.0	3.1	10.5	4.9	100.0

Table 9.14.2 shows the frequency of the most severe head injury with type of helmet coverage. The outstanding fact here is the overwhelming frequency of the unhelmeted rider, contributing approximately 80% of the cases of most severe head injury. Comparing helmet coverage in these injury data with helmet use by the accident-involved riders gives the following:

TABLE 9.14.2. FREQUENCY OF MOST SEVERE HEAD INJURY AND EFFECT OF HELMET USE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Partial	1.	10	3.5	18.2	18.2
Full	2.	25	8.7	45.5	63.6
Full Facial-105	3.	6	2.1	10.9	74.5
Full Facial-120	4.	14	4.9	25.5	100.0
Unknown	8.	4	1.4	Missing	100.0
N.A., No Helmet	9.	228	79.4	Missing	100.0
	TOTAL	287	100.0	100.0	

Helmet Coverage	Most Severe Head Injury	Use by the Accident Riders
Partial	10 (18.2%)	32 (9.4%)
Full	25 (45.5%)	197 (57.6%)
Full Facial	20 (36.4%)	113 (33.0%)

This comparison shows a significant over-representation for the partial coverage helmet. The partial coverage helmet does not protect the cranium and brain as well as other helmet configurations.

Table 9.14.3 shows the distribution of the motorcycle rider most severe head injuries and the effect of helmet use. The benefit of any kind of helmet is powerful as shown in these data. There is no significant difference in benefit from the full coverage or full facial coverage helmet because both helmet configurations cover the head completely. The partial coverage helmet is certainly more effective than no helmet at all, but its effectiveness is significantly below that of the full and full facial coverage helmets.

9.15 Effect of Helmet Coverage on Motorcycle Rider Most Severe Face Injury

There were 244 cases among the 900 on-scene, in-depth accident investigations where the motorcycle rider experienced injuries to the face. In this analysis, the injuries to the regions of the face are collected and the extreme values of injury severity are noted for each accident case. Table 9.15.1 shows the regions of the face and the frequency of the most severe face injury occurring in that region. Note that the mandible is the most frequent region of most severe facial injury.

An important point to note here is that the severe facial impacts are closely related to severe head injury. For example, a severe impact injury to the mandible can be accompanied by transmitted force to the skull and brain, and related injury.

TABLE 9.14.3. RIDER MOST SEVERE HEAD INJURY
INJURY SEVERITY BY TYPE OF HELMET WORN
(OSIDs)

Helmet Type	Count / Row Pct / Col Pct / Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
Partial		22	7	1	1	0	1	0	32
		68.8	21.9	3.1	3.1	0.0	3.1	0.0	3.6
		3.6	4.2	2.2	5.0	0.0	3.3	0.0	
		2.4	0.8	0.1	0.1	0.0	0.1	0.0	
Full		172	12	5	1	1	3	3	197
		87.3	6.1	2.5	0.5	0.5	1.5	1.5	21.9
		28.1	7.1	10.9	5.0	11.1	10.0	21.4	
		19.1	1.3	0.6	0.1	0.1	0.3	0.3	
Full Facial-105		8	4	2	0	0	0	0	14
		57.1	28.6	14.3	0.0	0.0	0.0	0.0	1.6
		1.3	2.4	4.3	0.0	0.0	0.0	0.0	
		0.9	0.4	0.2	0.0	0.0	0.0	0.0	
Full Facial-120		85	8	3	0	1	2	0	99
		85.9	8.1	3.0	0.0	1.0	2.0	0.0	11.0
		13.9	4.8	6.5	0.0	11.1	6.7	0.0	
		9.4	0.9	0.3	0.0	0.1	0.2	0.0	
Unknown		18	2	0	1	0	1	0	22
		81.8	9.1	0.0	4.5	0.0	4.5	0.0	2.4
		2.9	1.2	0.0	5.0	0.0	3.3	0.0	
		2.0	0.2	0.0	0.1	0.0	0.1	0.0	
N/A No Helmet		308	135	35	17	7	23	11	536
		57.5	25.2	6.5	3.2	1.3	4.3	2.1	59.6
		50.2	80.4	76.1	85.0	77.8	76.7	78.6	
		34.2	15.0	3.9	1.9	0.8	2.6	1.2	
	Column Total	613	168	46	20	9	30	14	900
		68.1	18.7	5.1	2.2	1.0	3.3	1.6	100.0

TABLE 9.15.1. REGION OF MOTORCYCLE RIDER MOST SEVERE FACE INJURY (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (5)
Frontal	F	42	17.2	17.2
Face-General	K	29	11.9	11.9
Mandible	M	68	27.9	27.9
Nasal	N	32	13.1	13.1
Orbit	R	32	13.1	13.1
Maxilla	X	12	4.9	4.9
Zygoma	Z	29	11.9	11.9
	TOTAL	244	100.0	100.0

Table 9.15.2 shows that these 244 most severe facial injuries are essentially symmetrical.

TABLE 9.15.2. SIDE OF MOTORCYCLE RIDER MOST SEVERE FACE INJURY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Bilateral	B	25	10.2	10.4
Central	C	49	20.1	20.4
Left	L	76	31.1	31.7
Midline	M	1	0.4	0.4
Right	R	89	36.5	37.1
Unknown	U	4	1.6	Missing
	TOTAL	244	100.0	100.0

Table 9.15.3 shows the crosstabulation of most severe face injury region and injury severity. Caution is due during evaluation of these data because of the close relation between facial impacts and head injury. For example, an injury to the maxilla or zygoma of moderate severity is sure to transmit at least moderate severity threat to the brain. So the data of 9.15.3 portray only the surface facial injury severity and the threat of transmitted force through this injury region is always a possibility.

The only serious and critical injury severities shown in Table 9.15.3 are related to injuries to the inferior frontal region. Of course, the chance of underlying brain injury is very high.

Table 9.15.4 shows the frequency of the most severe face injury and the effect of helmet use. Comparing helmet coverage in these injury data with helmet use by the accident-involved riders gives the following:

Helmet Coverage	Most Severe Face Injury	Use by the Accident Riders
Partial	6 (10.7%)	32 (9.4%)
Full	37 (66.1%)	197 (57.6%)
Full Facial	13 (23.2%)	113 (33.0%)

This comparison shows a definite underrepresentation of the full facial helmet coverage in these most severe facial injuries. The frequencies shown do not establish a high level of statistical significance but this underrpresentation must be considered with the concurrent advantage of reducing force transmitted to the brain from facial impact. This additional consideration increases the apparent advantage of the full facial coverage helmet, i.e., the additional coverage increases head protection as well as protecting the face.

TABLE 9.15.3. RIDER MOST SEVERE FACE INJURY REGION BY INJURY SEVERITY (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Row Total
F Frontal	37 88.1 18.1 15.2	2 4.8 6.7 0.8	0 0.0 0.0 0.0	1 2.4 100.0 0.4	2 4.8 100.0 0.8	42 17.2
K Face-General	28 96.6 13.7 11.5	1 3.4 3.3 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	29 11.9
M Mandible	54 79.4 26.5 22.1	11 16.2 36.7 4.5	3 4.4 42.9 1.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	68 27.9
N Nasal	24 75.0 11.8 9.8	8 25.0 26.7 3.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	32 13.1
R Orbit	25 78.1 12.3 10.2	3 9.4 10.0 1.2	4 12.5 57.1 1.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	32 13.1
X Maxilla	9 75.0 4.4 3.7	3 25.0 10.0 1.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	12 4.9
Z Zygoma	27 93.1 13.2 11.1	2 6.9 6.7 0.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	29 11.9
Column Total	204 83.6	30 12.3	7 2.9	1 0.4	2 0.8	244 100.0

TABLE 9.15.4. FREQUENCY OF MOST SEVERE FACE INJURY AND EFFECT OF HELMET USE (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Partial	1.	6	2.5	10.7
Full	2.	37	15.2	66.1
Full Facial-105	3.	1	0.4	1.8
Full Facial-120	4.	12	4.9	21.4
Unknown	8.	5	2.0	Missing
N.A.	9.	183	75.0	Missing
	TOTAL	244	100.0	100.0

Table 9.15.5 shows the distribution of the most severe face injuries and the effect of helmet use. The benefit of any kind of helmet is powerful as shown in these data. The benefit of the full facial coverage helmet is clearly evident, especially as AIS >1.

TABLE 9.15.5. RIDER MOST SEVERE FACE INJURY: INJURY SEVERITY BY TYPE OF HELMET WORN (OSIDs)

Helmet Type	Count / Row Pct / Col Pct / Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Row Total
Partial	Count	26	5	1	0	0	0	32
	Row Pct	81.3	15.6	3.1	0.0	0.0	0.0	3.6
	Col Pct	4.0	2.5	3.3	0.0	0.0	0.0	
	Tot Pct	2.9	0.6	0.1	0.0	0.0	0.0	
Full	Count	160	31	6	0	0	0	197
	Row Pct	81.2	15.7	3.0	0.0	0.0	0.0	21.9
	Col Pct	24.4	15.2	20.0	0.0	0.0	0.0	
	Tot Pct	17.8	3.4	0.7	0.0	0.0	0.0	
Full Facial-105	Count	13	1	0	0	0	0	14
	Row Pct	92.9	7.1	0.0	0.0	0.0	0.0	1.6
	Col Pct	2.0	0.5	0.0	0.0	0.0	0.0	
	Tot Pct	1.4	0.1	0.0	0.0	0.0	0.0	
Full Facial-120	Count	87	11	0	0	1	0	99
	Row Pct	87.9	11.1	0.0	0.0	1.0	0.0	11.0
	Col Pct	13.3	5.4	0.0	0.0	100.0	0.0	
	Tot Pct	9.7	1.2	0.0	0.0	0.1	0.0	
Unknown	Count	17	3	2	0	0	0	22
	Row Pct	77.3	13.6	9.1	0.0	0.0	0.0	2.4
	Col Pct	2.6	1.5	6.7	0.0	0.0	0.0	
	Tot Pct	1.9	0.3	0.2	0.0	0.0	0.0	
N.A. No Helmet	Count	353	153	21	7	0	2	536
	Row Pct	65.9	28.5	3.9	1.3	0.0	0.4	59.6
	Col Pct	53.8	75.0	70.0	100.0	0.0	100.0	
	Tot Pct	39.2	17.0	2.3	0.8	0.0	0.2	
Column Total		656	204	30	7	1	2	900
		72.9	22.7	3.3	0.8	0.1	0.2	100.0

The benefit of the full facial coverage helmet is somewhat expected because of the chin piece structure situated in front of the face, and the likelihood of the helmet being equipped with a face shield. The benefit of a full coverage helmet in reducing facial injury may not be so apparent but the full coverage helmet can offer significant impact protection to the frontal and orbital regions and part of the zygomatic regions. Also, the full coverage helmet may be equipped with a face shield, which may offer some load-spreading function.

9.16 Effect of Helmet Coverage on Motorcycle Rider Most Severe Neck Injury

There were 88 cases among the 900 on-scene, in-depth accident investigations where the motorcycle rider experienced neck injury. In the majority of

these cases (70 cases), the most severe neck injury was only a minor cervical sprain, or complaint of pain. Table 9.16.1 shows a crosstabulation of region and severity for the 88 most severe neck injury cases.

TABLE 9.16.1. RIDER MOST SEVERE NECK INJURY REGION BY SEVERITY (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Critical 5	Fatal 6	Row Total
C Cervical-General	70 94.6 97.2 79.5	1 1.4 100.0 1.1	0 0.0 0.0 0.0	1 1.4 50.0 1.1	2 2.7 28.6 2.3	74 84.1
Y Throat	1 100.0 1.4 1.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.1
1 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 16.7 50.0 1.1	5 83.3 71.4 5.7	6 6.8
2 Cervical Vertebra	1 50.0 1.4 1.1	0 0.0 0.0 0.0	1 50.0 16.7 1.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 2.3
5 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 33.3 2.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 2.3
6 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 100.0 33.3 2.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 2.3
7 Cervical Vertebra	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 16.7 1.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 1.1
Column Total	72 81.8	1 1.1	6 6.8	2 2.3	7 8.0	88 100.0

Table 9.16.2 shows the frequency of the most severe neck injury and the related type of helmet used. When combined with helmet use data, these data show an overall underrepresentation of helmet users in these neck injury cases, i.e., helmet users have less than their share of neck injuries.

TABLE 9.16.2. RIDER MOST SEVERE NECK INJURY FREQUENCY AND HELMET USE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Partial	1.	4	4.5	14.8
Full	2.	8	9.1	29.6
Full Facial-105	3.	2	2.3	7.4
Full Facial-120	4.	13	14.8	48.1
Unknown	8.	1	1.1	Missing
N.A. No Helmet	9.	60	68.2	Missing
	TOTAL	88	100.0	100.0

Helmet Coverage	Most Severe Neck Injury	Use by the Accident Riders
Partial	4 (14.8%)	32 (9.4%)
Full	8 (29.6%)	197 (57.6%)
Full Facial	15 (55.6%)	113 (33.0%)
None	60	536

However, the users of the full facial coverage helmets seem to fare no better than the unhelmeted riders, and do not exhibit the advantage obtained by the full coverage helmeted riders. The differences between the helmet coverage are significant and deserve elaboration. If all helmeted riders are compared for all unhelmeted riders, a slight advantage is shown but the measure of statistical significance is not high.

	No Neck Injury	Neck Injury	Total
Helmeted Riders	315	27	342
Unhelmeted Riders	476	60	536
Total	791	87	878

$(\chi^2 = 2.19)$

However, if these data are separated to exclude full facial coverage helmet use, there is higher significance to the advantage for helmet use.

Helmet Use	No Neck Injury	Neck Injury	Total
Partial and Full Coverage	217	12	229
No Helmet Use	476	60	536
Total	693	72	765

(χ^2 = 5.99)

One final set of these data establish the relation of the full facial coverage helmet to neck injury,

Helmet Use	No Neck Injury	Neck Injury	Total
Full Facial Coverage Only	98	15	113
No Helmet Use	476	60	536
Total	574	75	649

(χ^2 = 0.22)

Here the full facial coverage helmet shows a slight but insignificant overrepresentation, i.e., the full facial coverage helmet has essentially no significant effect on neck injury. There is no advantage but yet there is no disadvantage.

These comparisons need recall of the competing factors which affect helmet relation to neck injury. The helmet mass could contribute to neck injuries which are caused by "whiplash" or inertial loading. However, the more usual motorcycle accident involves the rider hitting his head on something then the helmet attenuates head impact and thus limits resulting neck motion. It is clear from these data that the lighter partial and full coverage helmets have a significant beneficial effect reducing neck injury, and the full facial coverage helmet simply has no significant effect. The principal observation is that there is <u>no adverse effect</u> and <u>no vulnerability</u> to neck injury from helmet use.

Table 9.16.3 provides a crosstabulation of helmet coverage and injury severity for the most severe neck injury in the 88 accident cases. A case-by-case review of the nine <u>critical</u> and <u>fatal</u> neck injury cases discloses no substantial arguments that helmet participation was a critical event, i.e., helmet use did not cause - and helmet use would not have prevented - these spectacular critical and fatal neck injuries.

However, for all other lower levels of the neck injury severity, helmet use has a <u>favorable</u> effect on neck injury.

TABLE 9.16.3. RIDER MOST SEVERE NECK INJURY: INJURY SEVERITY BY TYPE OF HELMET WORN (OSIDs)

Helmet Type / Count / Row Pct / Col Pct / Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Critical 5	Fatal 6	Row Total
Partial	28	4	0	0	0	0	32
	87.5	12.5	0.0	0.0	0.0	0.0	3.6
	3.4	5.6	0.0	0.0	0.0	0.0	
	3.1	0.4	0.0	0.0	0.0	0.0	
Full	189	7	0	1	0	0	197
	95.9	3.6	0.0	0.5	0.0	0.0	21.9
	23.3	9.7	0.0	16.7	0.0	0.0	
	21.0	0.8	0.0	0.1	0.0	0.0	
Full Facial-105	12	1	0	0	0	1	14
	85.7	7.1	0.0	0.0	0.0	7.1	1.6
	1.5	1.4	0.0	0.0	0.0	14.3	
	1.3	0.1	0.0	0.0	0.0	0.1	
Full Facial-120	86	1	0	0	0	2	99
	86.9	11.1	0.0	0.0	0.0	2.0	11.0
	10.6	15.3	0.0	0.0	0.0	28.6	
	9.6	1.2	0.0	0.0	0.0	0.2	
Unknown	21	1	0	0	0	0	22
	95.5	4.5	0.0	0.0	0.0	0.0	2.4
	2.6	1.4	0.0	0.0	0.0	0.0	
	2.3	0.1	0.0	0.0	0.0	0.0	
N.A. No Helmet	476	48	1	5	2	4	536
	88.8	9.0	0.2	0.9	0.4	0.7	59.6
	58.6	66.7	100.0	83.3	100.0	57.1	
	52.9	5.3	0.1	0.6	0.2	0.4	
Column Total	812	72	1	6	2	7	900
	90.2	8.0	0.1	0.7	0.2	0.8	100.0

9.17 Effect of Eye Protection on Motorcycle Rider Most Severe Face Injury

As in the previous sections, it was noted that 244 of the 900 on-scene, in-depth accident cases involved some facial region injury to the motorcycle rider. In the 244 cases, most of the riders were not using any sort of eye protection such as face shields and goggles, and most of the riders were not using helmets.

Table 9.17.1 shows the eye protection used by the motorcycle riders in the 244 cases where facial injuries were experienced. Note that the most common eye protection used was the wrap around face shield, which is a helmet appliance.

Table 9.17.2 shows the crosstabulation of motorcycle rider most severe face injury region and severity. Note that injuries to the mandible are most frequent in these data.

TABLE 9.17.1. MOTORCYCLE RIDER MOST SEVERE FACE INJURY AND EYE PROTECTION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
None	0.	197	80.7	85.7
Goggles	1.	4	1.6	1.7
Wrap-around Face Shield	2.	19	7.8	8.3
Bubble Type Face Shield	3.	5	2.0	2.2
Visor-face Shield	4.	5	2.0	2.2
Unknown	8.	14	5.7	Missing
	TOTAL	244	100.0	100.0

Table 9.17.3 shows the crosstabulation of the most severe face injury severity with the various types of eye protection. A condensation of these data provides the following comparison:

Eye Protection	No Face Injury	Face Injury	Total
None	436	197	633
Goggles, Face Shields, etc.	185	33	218
Total	621	230	851

(χ^2 = 20.2)

This comparison shows a significant difference in the frequency of face injury between protected and unprotected riders. However, the benefit is not due exclusively to the eye protection; the benefit is due in part to the helmet to which the appliance is attached. The helmet can offer substantial protection to the frontal, orbital and part of the zygomatic regions, and to all other areas if the helmet has full facial coverage.

There is just no way that any optical quality acetate, acrylic or polycarbonate face shield can offer substantial impact energy absorption. The only function available from the face shield is minor load-spreading and abrasion protection. Fortunately, 83.6% of those facial injuries are minor and apparently within this level of protection.

The most important observation here is that the combination of a helmet and eye protection will be extremely powerful in reducing face injuries. Of course, the most effective helmet configuration would be the full facial coverage.

TABLE 9.17.2. RIDER MOST SEVERE FACE INJURY: INJURY SEVERITY BY INJURY REGION (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Row Total
F Frontal	37 88.1 18.1 15.2	2 4.8 6.7 0.8	0 0.0 0.0 0.0	1 2.4 100.0 0.4	2 4.8 100.0 0.8	42 17.2
K Face-General	28 96.6 13.7 11.5	1 3.4 3.3 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	29 11.9
M Mandible	54 79.4 26.5 22.1	11 16.2 36.7 4.5	3 4.4 42.9 1.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	68 27.9
N Nasal	24 75.0 11.8 9.8	8 25.0 26.7 3.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	32 13.1
R Orbit	25 78.1 12.3 10.2	3 9.4 10.0 1.2	4 12.5 57.1 1.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	32 13.1
X Maxilla	9 75.0 4.4 3.7	3 25.0 10.0 1.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	12 4.9
Z Zygoma	27 93.1 13.2 11.1	2 6.9 6.7 0.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	29 11.9
Column Total	204 83.6	30 12.3	7 2.9	1 0.4	2 0.8	244 100.0

TABLE 9.17.3. RIDER MOST SEVERE FACE INJURY: INJURY SEVERITY BY EYE PROTECTION TYPE (OSIDs)

Count Row Pct Col Pct Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Row Total
None	407 68.4 62.0 45.2	160 26.9 78.4 17.8	22 3.7 73.3 2.4	4 0.7 57.1 0.4	0 0.0 0.0 0.0	2 0.3 100.0 0.2	595 66.1
N.A.	29 76.3 4.4 3.2	7 18.4 3.4 0.8	1 2.6 3.3 0.1	1 2.6 14.3 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	38 4.2
Goggles	24 85.7 3.7 2.7	2 7.1 1.0 0.2	1 3.6 3.3 0.1	1 3.6 14.3 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	28 3.1
Wrap Around Face Shield	95 83.3 14.5 10.6	17 14.9 8.3 1.9	1 0.9 3.3 0.1	0 0.0 0.0 0.0	1 0.9 100.0 0.1	0 0.0 0.0 0.0	114 12.7
Bubble Type Face Shield	33 86.8 5.0 3.7	4 10.5 2.0 0.4	1 2.6 3.3 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	38 4.2
Visor-Face Shield	28 84.8 4.3 3.1	5 15.2 2.6 0.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	33 3.7
Other	5 100.0 0.8 0.6	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	5 0.6
Unknown	35 71.4 5.3 3.9	9 18.4 4.4 1.0	4 8.2 13.3 0.4	1 2.0 14.3 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	49 5.4
Column Total	656 72.9	204 22.7	30 3.3	7 0.8	1 0.1	2 0.2	900 100.0

9.18 Effect of Eye Protection on Motorcycle Rider Most Severe Eye Injury

There were 46 cases among the 900 on-scene in-depth accident investigations where the motorcycle rider experienced injury in the specific region of the orbit. Protection from injury in this region may appear to be a simple matter of wearing some sort of eye protection but actually the protection problem has several subtle factors involved.

Table 9.18.1 shows the nature of those injuries in the region of the orbit of the accident-involved motorcycle rider. The injuries are noted to be primarily symmetrical lacerations and abrasions to the integument. Actual injuries to the visual system are rare; only two of the injuries noted included the eye itself. Table 9.18.2 shows the effect of helmet use, helmet coverage and eye protection on motorcycle rider eye (region) injuries.

TABLE 9.18.1. MOTORCYCLE RIDER EYE INJURIES SYSTEM ORGAN, LESION AND SIDE OF ORBIT REGION INJURIES (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
System-Organ				
Integumentary	I	41	89.1	89.1
Skeletal	S	3	6.5	6.5
All Systems in Region	W	1	2.2	2.2
Eye	Y	1	2.2	2.2
	TOTAL	46	100.0	100.0
Lesion				
Abrasion	A	10	21.7	21.7
Contusion	C	4	8.7	8.7
Fracture	F	3	6.5	6.5
Hemorrhage	H	1	2.2	2.2
Hematoma	J	3	6.5	6.5
Laceration	L	23	50.0	50.0
Avulsion	V	2	4.3	4.3
	TOTAL	46	100.0	100.0
Side				
Bilateral	B	1	2.2	2.2
Left	L	24	52.2	52.2
Right	R	21	45.7	45.7
	TOTAL	46	100.0	100.0

TABLE 9.18.2. EFFECT OF HELMET USE, HELMET COVERAGE, AND EYE PROTECTION TYPE ON RIDER EYE INJURIES (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
With Helmet	1.	7	15.2	15.5
Without Helmet	3.	38	82.6	84.5
Unknown	8.	1	2.2	Missing
	TOTAL	46	100.0	100.0
Helmet Coverage				
Partial	1.	2	4.3	33.3
Full	2.	3	6.5	50.0
Full Facial-120	4.	1	2.2	16.7
Unknown	8.	2	4.3	Missing
N.A. No Helmet	9.	38	82.6	Missing
	TOTAL	46	100.0	100.0
Eye Protection				
None	0.	34	73.9	82.9
Goggles	1.	1	2.2	2.4
Wrap-around Face Shield	2.	2	4.3	4.9
Bubble Type Face Shield	3.	2	4.3	4.9
Visor-Face Shield	4.	2	4.3	4.9
Unknown	8.	5	10.9	Missing
	TOTAL	46	100.0	100.0

Table 9.18.3 shows a crosstabulation of eye (region) injuries and eye protection. In general, these data show the great advantage in eye (region) protection for those riders using eye protection. However, the protection devices shown in these data are most usually the appliances attached to helmets so the benefit of protection results from the combined effect of the helmet and the appliance.

Previous sections have described the very high frequency of the accident-involved riders failing to use any kind of eye protection or eyeglasses. It appears that the principal function of eye coverage is the preservation of good vision to avoid accident involvement. Visual system injuries are rare and the combination of the contemporary safety helmet and face shield offer a high level of protection from eye (region) injury.

9.19 Motorcycle Rider Most Severe Injury, Somatic (Body) Regions

In order to provide a perspective for injury prevention, the somatic injuries were evaluated to determine the injury of highest severity in each of the 900 on-scene, in-depth accident cases. Table 9.19.1 provides a crosstabulation of this rider most severe somatic injury severity and body region.

TABLE 9.18.3. RIDER MOST SEVERE EYE REGION INJURY: INJURY SEVERITY BY EYE PROTECTION (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Row Total
None	29 85.3 74.4 63.0	3 8.8 100.0 6.5	2 5.9 50.0 4.3	34 73.9
Goggles	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 25.0 2.2	1 2.2
Wrap Around Face Shield	2 100.0 5.1 4.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 4.3
Bubble Type Face Shield	2 100.0 5.1 4.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 4.3
Visor-Face Shield	2 100.0 5.1 4.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 4.3
Unknown	4 80.0 10.3 8.7	0 0.0 0.0 0.0	1 20.0 25.0 2.2	5 10.9
Column Total	39 84.8	3 6.5	4 8.7	46 100.0

These injuries are essentially symmetrical, mostly integumentary (46.8%), mostly abrasions (26.7%), contusions (17.9%) and lacerations (10.2%). This implies that coverage of the somatic regions with heavy garments of thick cloth and leather has a great prospect of injury reduction. However, fractures and dislocations are 28.1% of these most severe injuries and convenient countermeasure is not so obvious.

The data of 9.19.1 show that injuries to the hip, thigh, knee, lower leg, ankle and foot total 56.4% of these most severe injuries. However, injuries to these regions are perhaps disabling but not deadly. The lethal somatic injuries are primarily those to the chest, and abdomen. These most severe somatic injuries at serious, critical and fatal levels are very high energy injuries and effective protection systems are truly limited.

TABLE 9.19.1. RIDER MOST SEVERE SOMATIC INJURY: INJURY SEVERITY BY INJURY REGION (OSIDs)

Count Row Pct Col Pct Tot Pct	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
A Upper Arm	19 73.1 3.9 2.2	3 11.5 1.6 0.3	3 11.5 2.8 0.3	1 3.8 1.9 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	26 3.0
B Back	29 82.9 5.9 3.4	3 8.6 1.6 0.3	3 8.6 2.8 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	35 4.0
C Chest	6 11.5 1.2 0.7	7 13.5 3.8 0.8	10 19.2 9.3 1.2	2 3.8 3.7 0.2	17 32.7 85.0 2.0	10 19.2 90.9 1.2	52 6.0
E Elbow	27 77.1 5.5 3.1	5 14.3 2.7 0.6	3 8.6 2.8 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	35 4.0
K Knee	80 70.8 16.3 9.2	21 18.6 11.5 2.4	10 8.8 9.3 1.2	2 1.8 3.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	113 13.1
L Lower Leg	78 45.1 15.9 9.0	33 19.1 18.0 3.8	30 17.3 28.0 3.5	32 18.5 59.3 3.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	173 20.0
M Abdomen	22 48.9 4.5 2.5	11 24.4 6.0 1.3	4 8.9 3.7 0.5	5 11.1 9.3 0.6	3 6.7 15.0 0.3	0 0.0 0.0 0.0	45 5.2
O Whole Body	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 100.0 9.1 0.1	1 0.1
P Pelvic Hip	43 75.4 8.8 5.0	3 5.3 1.6 0.3	9 15.8 8.4 1.0	2 3.5 3.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	57 6.6
Q Ankle Foot	36 41.9 7.3 4.2	39 45.3 21.3 4.5	10 11.6 9.3 1.2	1 1.2 1.9 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	86 9.9
R Forearm	32 71.1 6.5 3.7	4 8.9 2.2 0.5	3 6.7 2.8 0.3	6 13.3 11.1 0.7	0 0.0 0.0 0.0	0 0.0 0.0 0.0	45 5.2
S Shoulders	23 50.0 4.7 2.7	13 28.3 7.1 1.5	10 21.7 9.3 1.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	46 5.3
T Thigh	31 52.5 6.3 3.6	17 28.8 9.3 2.0	9 15.3 8.4 1.0	2 3.4 3.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	59 6.8
W Wrist-Hand	63 70.8 12.9 7.3	22 24.7 12.0 2.5	3 3.4 2.8 0.3	1 1.1 1.9 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	89 10.3
X Upper Extremities	0 0.0 0.0 0.0	1 100.0 0.5 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.1
Y Trunk	1 50.0 0.2 0.1	1 50.0 0.5 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
Column Total	490 56.6	183 21.2	107 12.4	54 6.2	20 2.3	11 1.3	865 100.0

9.20 Effect of Upper Torso Garment on Most Severe Upper Torso Injury

Table 9.20.1 shows the type of upper torso garment worn by the motorcycle rider and the investigator evaluation of that garment in prevention or reduction of injury. Table 9.20.2 shows the type of upper torso garment worn by the passenger and the investigator's evaluation of that garment in prevention or reduction of injury. In general, these accident cases showed that the heavier garment prevented or reduced minor and moderate injuries of abrasion. Obviously no leather jacket will prevent a dislocated shoulder or rib fracture so the expectations were for abrasion protection primarily.

TABLE 9.20.1. MOTORCYCLE·RIDER UPPER TORSO GARMENT AND INVESTIGATOR EVALUATION OF EFFECTIVENESS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Garment					
None	0.	14	1.6	1.6	1.6
Light Cloth	1.	248	27.6	28.9	30.5
Medium Cloth	2.	226	25.1	26.3	56.9
Heavy Cloth	3.	303	33.7	35.3	92.2
Leather	4.	67	7.4	7.8	100.0
Unknown	8.	42	4.7	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	88	9.8	10.7	10.7
Yes	1.	456	50.7	55.7	66.4
No	2.	275	30.6	33.6	100.0
Unknown	8.	32	3.6	Missing	100.0
N.A.	9.	49	5.4	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.20.3 shows a crosstabulation of motorcycle rider most severe upper torso injury severity and the effect of upper torso garment. The heavier upper torso garments clearly contribute a significant protection, especially for the lower levels of injury severity. A condensation of these data provides the following perspective.

Upper Torso Coverage	No Injury	Injury	Total
None, light and medium	207	281	488
Heavy cloth, leather	189	181	370
Total	396	462	858

(χ^2 = 6.01)

TABLE 9.20.2. PASSENGER UPPER TORSO GARMENT AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Garment					
None	0.	1	0.1	0.7	0.7
Light Cloth	1.	54	6.0	37.8	38.5
Medium Cloth	2.	40	4.4	28.0	66.4
Heavy Cloth	3.	40	4.4	28.0	94.4
Leather	4.	8	0.9	5.6	100.0
Unknown	8.	9	1.0	Missing	100.0
N.A.	9.	748	83.1	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	25	2.8	18.5	18.5
Yes	1.	63	7.0	46.7	65.2
No	2.	47	5.2	34.8	100.0
Unknown	8.	9	1.0	Missing	100.0
N.A.	9.	756	84.0	Missing	100.0
	TOTAL	900	100.0	100.0	

This grouping of coverage and injury provides a simple comparison of the significant benefit of the heavy denim or leather jacket. Of course, this comparison is well known to those riders who have experienced "road rash" or have ruined leathers. Either experience is as meaningful as the above data; but one of the two is a more difficult experience.

9.21 Effect of Lower Torso Coverage on Most Severe Lower Torso Injury

Table 9.21.1 shows the type of lower torso garment worn by the motorcycle rider and the investigator's evaluation of that garment in the prevention or reduction of injury. Table 9.21.2 shows the type of lower torso garment worn by the passenger and the investigator's opinion of that garment in the prevention or reduction of injury. In Table 9.21.1 the code of "None" was selected to represent the equivalent protection offered by a Speedo bathing suit. No bona fide streakers were encountered in these accidents. In general, these accident cases showed that heavier garments prevented or reduced minor and moderate injuries of abrasion. Obviously, no set of custom leathers will prevent a compound, comminuted fracture of the tibia and fibula trapped between an automobile bumper and the motorcycle. The expectations were for the heavier garments to resist abrasion only.

TABLE 9.20.3. RIDER MOST SEVERE UPPER TORSO INJURY: INJURY SEVERITY BY UPPER TORSO GARMENT (OSIDs)

Count Row Pct Col Pct Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Fatal 6	Row Total
None	3 21.4 0.7 0.3	8 57.1 2.3 0.9	0 0.0 0.0 0.0	2 14.3 5.1 0.2	0 0.0 0.0 0.0	1 7.1 4.8 0.1	0 0.0 0.0 0.0	14 1.6
Light Cloth	103 41.5 24.6 11.4	107 43.1 30.5 11.9	21 8.5 40.4 2.3	10 4.0 25.6 1.1	2 0.8 25.0 0.2	4 1.6 19.0 0.4	1 0.4 10.0 0.1	248 27.6
Medium Cloth	101 44.7 24.1 11.2	98 43.4 27.9 10.9	13 5.8 25.0 1.4	8 3.5 20.5 0.9	2 0.9 25.0 0.2	3 1.3 14.3 0.3	1 0.4 10.0 0.1	226 25.1
Heavy Cloth	152 50.2 36.3 16.9	110 36.3 31.3 12.2	11 3.6 21.2 1.2	13 4.3 33.3 1.4	2 0.7 25.0 0.2	7 2.3 33.3 0.8	8 2.6 80.0 0.9	303 33.7
Leather	37 55.2 8.8 4.1	21 31.3 6.0 2.3	4 6.0 7.7 0.4	3 4.5 7.7 0.3	0 0.0 0.0 0.0	2 3.0 9.5 0.2	0 0.0 0.0 0.0	67 7.4
Unknown	23 54.8 5.5 2.6	7 16.7 2.0 0.8	3 7.1 5.8 0.3	3 7.1 7.7 0.3	2 4.8 25.0 0.2	4 9.5 19.0 0.4	0 0.0 0.0 0.0	42 4.7
Column Total	419 46.6	351 39.0	52 5.8	39 4.3	8 0.9	21 2.3	10 1.1	900 100.0

TABLE 9.21.1. MOTORCYCLE RIDER LOWER TORSO GARMENT AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Garment					
None	0.	2	0.2	0.2	0.2
Light Cloth	1.	40	4.4	4.7	4.9
Medium Cloth	2.	664	73.8	77.3	82.2
Heavy Cloth	3.	149	16.6	17.3	99.5
Leather	4.	4	0.4	0.5	100.0
Unknown	8.	41	4.6	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	21	2.3	2.6	2.6
Yes	1.	349	38.8	43.4	46.0
No	2.	435	48.3	54.0	100.0
Unknown	8.	24	2.7	Missing	100.0
N.A.	9.	71	7.9	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.21.2. PASSENGER LOWER TORSO GARMENT AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Garment					
Light Cloth	1.	8	0.9	5.6	5.6
Medium Cloth	2.	124	13.8	87.3	93.0
Heavy Cloth	3.	10	1.1	7.0	100.0
Unknown	8.	10	1.1	Missing	100.0
N.A.	9.	748	83.1	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	6	0.7	4.4	4.4
Yes	1.	64	7.1	46.7	51.1
No	2.	67	7.4	48.9	100.0
Unknown	8.	7	0.8	Missing	100.0
N.A.	9.	756	84.0	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.21.3 shows a crosstabulation of motorcycle rider most severe lower torso injury severity and the effect of the lower torso garment. A condensation of these data provides the following comparison:

Lower Torso Coverage	No Injury	Injury	Total
None, Light and Medium	104	602	706
Heavy Cloth, Leather	32	121	153
Total	132	723	859

$(\chi^2 = 3.16)$

TABLE 9.21.3. RIDER MOST SEVERE LOWER TORSO INJURY: INJURY SEVERITY BY LOWER TORSO GARMENT (OSIDs)

Count Row Pct Col Pct Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Critical 5	Unknown 8	Row Total
None	2 100.0 1.4 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.2
Light Cloth	3 7.5 2.0 0.3	21 52.5 4.0 2.3	10 25.0 9.4 1.1	2 5.0 2.8 0.2	4 10.0 9.3 0.4	0 0.0 0.0 0.0	0 0.0 0.0 0.0	40 4.4
Medium Cloth	99 14.9 66.9 11.0	397 59.8 75.3 44.1	73 11.0 68.9 8.1	61 9.2 84.7 6.8	31 4.7 72.1 3.4	2 0.3 66.7 0.2	1 0.2 100.0 0.1	664 73.8
Heavy Cloth	31 20.8 20.9 3.4	89 59.7 16.9 9.9	15 10.1 14.2 1.7	7 4.7 9.7 0.8	7 4.7 16.3 0.8	0 0.0 0.0 0.0	0 0.0 0.0 0.0	146 16.6
Leather	1 25.0 0.7 0.1	3 75.0 0.6 0.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	4 0.4
Unknown	12 29.3 8.1 1.3	17 41.5 3.2 1.9	8 19.5 7.5 0.9	2 4.9 2.8 0.2	1 2.4 2.3 0.1	1 2.4 33.3 0.1	0 0.0 0.0 0.0	41 4.6
Column Total	148 16.4	527 58.6	106 11.8	72 8.0	43 4.8	3 0.3	1 0.1	900 100.0

In these data, the heavy cloth and leather lower torso garments show an underrepresentation in injury, but not at high level of significance. The benefit of the heavy garment in reducing abrasion injury is truly without question;

the prospect of any heavy garment in reducing contusion, fracture, dislocation, etc., is weak indeed. As in the upper torso garment analysis, the heavy garment has the most reasonable expectation of reducing "road rash".

9.22 Effect of Foot Coverage on Most Severe Ankle-Foot Injury

Table 9.22.1 shows the motorcycle rider footwear coverage and the investigator evaluation of that footwear in the prevention or reduction of injury. Table 9.22.2 shows the passenger footwear coverage and the investigator evaluation of that footwear in the prevention or reduction of injury. It was typical that some motorcycle riders appreciated the benefit of heavy shoes or boots since 39.6% of the accident-involved riders were using heavy duty footwear. In general the use of heavy shoes or boots reduced the low severity injuries to the ankle and foot. This was particularly obvious in the prevention of minor and moderate abrasions to the ankle and foot.

TABLE 9.22.1. MOTORCYCLE RIDER FOOT COVERAGE AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Foot Coverage					
None	0.	3	0.3	0.4	0.4
Sandal, Loafer	1.	147	16.3	17.4	17.7
Street Shoe	2.	340	37.8	40.2	57.9
Boot	3.	356	39.6	42.1	100.0
Unknown	8.	54	6.0	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	139	15.4	16.6	16.6
Yes	1.	540	60.0	64.6	81.2
No	2.	157	17.4	18.8	100.0
Unknown	8.	49	5.4	Missing	100.0
N.A.	9.	15	1.7	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.22.2. PASSENGER FOOT COVERAGE AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Foot Coverage					
None	0.	5	0.6	3.6	3.6
Sandal, Loafer	1.	45	5.0	32.4	36.0
Street Shoe	2.	60	6.7	43.2	79.1
Boot	3.	29	3.2	20.9	100.0
Unknown	8.	13	1.4	Missing	100.0
N.A.	9.	748	83.1	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	36	4.0	27.5	27.5
Yes	1.	62	6.9	47.3	74.8
No	2.	33	3.7	25.2	100.0
Unknown	8.	15	1.7	Missing	100.0
N.A.	9.	754	83.8	Missing	100.0
	TOTAL	900	100.0	100.0	

Table 9.22.3 shows the crosstabulation of motorcycle rider most severe ankle-foot injury severity and the foot coverage. The benefits of protection by the use of heavy shoes and boots is evident at all levels of injury. The overall effect is shown by the following comparison:

Foot Coverage	No Injury	Ankle-foot Injury	Total
None, sandals, athletic and medium weight shoes	348	142	490
Heavy shoes and boots	288	68	356
Total	636	210	846

$(\chi^2 = 10.26)$

In these data, the heavy shoes and boots demonstrate an advantage of protection which is highly significant. Alternately, these data may portray the vulnerability to ankle-foot injury for those motorcycle riders wearing only light footwear, or nothing at all.

TABLE 9.22.3. RIDER MOST SEVERE ANKLE-FOOT INJURY: INJURY SEVERITY BY ANKLE-FOOT COVERAGE (OSIDs)

Count Row Pct Col Pct Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Row Total
None	1 33.3 0.1 0.1	1 33.3 0.7 0.1	1 33.3 1.5 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 0.3
Light Sandal	96 65.3 14.2 10.7	37 25.2 26.6 4.1	11 7.5 16.7 1.2	3 2.0 18.8 0.3	0 0.0 0.0 0.0	147 16.3
Medium St Shoes	251 73.8 37.0 27.9	58 17.1 41.7 6.4	23 6.8 34.8 2.6	7 2.1 43.8 0.8	1 0.3 100.0 0.1	340 37.8
Heavy Shoes-Boot	288 80.9 42.5 32.0	37 10.4 26.6 4.1	28 7.9 42.4 3.1	3 0.8 18.8 0.3	0 0.0 0.0 0.0	356 39.6
Unknown	42 77.8 6.2 4.7	6 11.1 4.3 0.7	3 5.6 4.5 0.3	3 5.6 18.8 0.3	0 0.0 0.0 0.0	54 6.0
Column	678 75.3	139 15.4	66 7.3	16 1.8	1 0.1	900 100.0

A heavy shoe or boot has the possibility of preventing or reducing injury to the lower leg, as well as the ankle and foot. Table 9.22.4 shows a cross-tabulation of the most severe injury to the region of the lower leg, ankle and foot and the foot coverage. This grouping of most severe injuries now includes those much more severe fractures of the distal half of the lower leg - which would be difficult to prevent or reduce even with the use of heavy motocross boots. A condensation of these data provides the following comparison:

Foot Coverage	No Injury	Lower-leg, Ankle-foot Injury	Total
None, sandals athletic and medium weight shoes	201	289	490
Heavy shoes and boots	171	185	356
Total	372	474	846

(χ^2 = 3.84)

TABLE 9.22.4. RIDER MOST SEVERE INJURY TO ANKLE-FOOT AND LOWER LEG INJURY SEVERITY BY FOOT COVERAGE (OSIDs)

Count Row Pct Col Pct Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Unknown 8	Row Total
None	1 33.3 0.3 0.1	0 0.0 0.0 0.0	2 66.7 2.1 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 0.3
Light Sandal	58 39.5 14.7 6.4	56 38.1 17.2 6.2	19 12.9 20.0 2.1	8 5.4 16.7 0.9	6 4.1 17.1 0.7	0 0.0 0.0 0.0	147 16.3
Medium St. Shoes	142 41.8 35.9 15.8	133 39.1 40.8 14.8	35 10.3 36.8 3.9	17 5.0 35.4 1.9	12 3.5 34.3 1.3	1 0.3 100.0 0.1	340 37.8
Heavy Shoes-Boots	171 48.0 43.3 19.0	115 32.3 35.3 12.8	35 9.8 36.8 3.9	19 5.3 39.6 2.1	16 4.5 45.7 1.8	0 0.0 0.0 0.0	356 39.6
Unknown	23 42.6 5.8 2.6	22 40.7 6.7 2.4	4 7.4 4.2 0.4	4 7.4 8.3 0.4	1 1.9 2.9 0.1	0 0.0 0.0 0.0	54 6.0
Column Total	395 43.9	326 36.2	95 10.6	48 5.3	35 3.9	1 0.1	900 100.0

This comparison shows that the benefit of the heavy shoes and boots is significant in the overall evaluation. However, this benefit exists primarily at the low levels of injury severity and is due mostly to the reduced injury to the ankle and foot.

Also, there was no case where the heavy shoe or boot aggravated injury. These cases showed no vulnerability to injury from the use of heavy protective footwear.

9.23 Effect of Hand Protection on Most Severe Hand Injury

Table 9.23.1 shows the type of motorcycle rider hand protection and the investigator evaluation of that hand protection in preventing or reducing hand injury. Table 9.23.2 shows the type of passenger hand protection and the investigators evaluation of that hand protection in preventing or reducing hand injury. In general, these accident cases showed that the heavier glove or gauntlet prevented or reduced minor and moderate injuries of abrasion. Obviously, no glove or gauntlet has the ability to prevent wrist fracture or dislocation so the expectations were for abrasion protection only.

TABLE 9.23.1. MOTORCYCLE RIDER HAND PROTECTION AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	522	58.0	61.5	61.5
Light	1.	34	3.8	4.0	65.5
Medium	2.	128	14.2	15.1	80.6
Heavy	3.	165	18.3	19.4	100.0
Unknown	8.	51	5.7	Missing	100.0
	TOTAL	900	100.0	100.0	
No Contact	0.	113	12.6	27.8	27.8
Yes	1.	263	29.2	64.6	92.4
No	2.	31	3.4	7.6	100.0
Unknown	8.	56	6.2	Missing	100.0
N.A.	9.	437	48.6	Missing	100.0
	TOTAL	900	100.0	100.0	

TABLE 9.23.2. PASSENGER HAND PROTECTION AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Coverage					
None	0.	131	14.6	91.0	91.0
Light	1.	2	0.2	1.4	92.4
Medium	2.	6	0.7	4.2	96.5
Heavy	3.	5	0.6	3.5	100.0
Unknown	8.	8	0.9	Missing	100.0
N.A.	9.	748	83.1	Missing	100.0
	TOTAL	900	100.0	100.0	
Effective?					
No Contact	0.	34	3.8	75.6	75.6
Yes	1.	10	1.1	22.2	97.8
No	2.	1	0.1	2.2	100.0
Unknown	8.	9	1.0	Missing	100.0
N.A.	9.	846	94.0	Missing	100.0
	TOTAL	900	100.0	100.0	

The most severe injuries to the wrist-hand region of the motorcycle riders were collected separately for analysis. Table 9.23.3 shows the hand protection involved in these 288 accident cases, and the investigator evaluation of the effectiveness of this rider hand coverage. Table 9.23.4 shows the type and side of lesion in these 288 cases for the most severe wrist-hand injury. Abrasions predominate in this type of lesion and it is clear that heavy gloves or gauntlets can provide protection for this type of injury. These most severe wrist-hand injuries are essentially symmetrical.

TABLE 9.23.3. RIDER HAND PROTECTION FOR MOST SEVERE WRIST-HAND INJURY AND INVESTIGATOR EVALUATION OF EFFECTIVENESS (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Coverage					
None	0.	190	66.0	69.6	69.6
Light	1.	13	4.5	4.8	74.4
Medium	2.	30	10.4	11.0	85.3
Heavy	3.	40	13.9	14.7	100.0
Unknown	8.	15	5.2	Missing	100.0
	TOTAL	288	100.0	100.0	
Effective?					
Yes	1.	58	20.1	70.7	70.7
No	2.	24	8.3	29.3	100.0
No Contact	0.	4	1.4	Missing	100.0
Unknown	8.	13	4.5	Missing	100.0
N.A.	9.	189	65.6	Missing	100.0
	TOTAL	288	100.0	100.0	

In addition, the lesions of fracture and dislocation to the region of the wrist-hand are shown to be 19.8% of these most severe injuries. Such severe injuries are not preventable by the use of heavy gloves or gauntlets, but the combination of fractures and dislocations with severe abrasions complicates injury management.

Table 9.23.5 provides a crosstabulation of the motorcycle rider most severe wrist injury severity and hand protection. These data show a significant advantage to the use of medium and heavy gloves and gauntlets. Light hand protection such as handball gloves, cloth gloves, etc., offer no significant protection, as is illustrated with the following data:

Hand Coverage	No Injury	Wrist-Hand Injury	Total
None	332	190	522
Light Gloves	21	13	34
Total	353	203	556

$(\chi^2 = 0)$

TABLE 9.23.4. MOTORCYCLE RIDER MOST SEVERE WRIST-HAND INJURY TYPE AND SIDE OF LESION (OSIDs)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
<u>Type</u>				
Abrasion	A	147	51.0	51.0
Burn	B	1	0.3	0.3
Contusion	C	17	5.9	5.9
Dislocation	D	4	1.4	1.4
Fracture	F	53	18.4	18.4
Swelling	G	3	1.0	1.0
Hemorrhage	H	1	0.3	0.3
Laceration	L	23	8.0	8.0
Amputation	M	2	0.7	0.7
Pain	P	14	4.9	4.9
Sprain	S	22	7.6	7.6
Avulsion	V	1	0.3	0.3
	TOTAL	288	100.0	100.0
<u>Side</u>				
Bilateral	B	53	18.4	18.4
Left	L	111	38.5	38.5
Right	R	123	42.7	42.7
Unknown	U	1	0.3	0.0
	TOTAL	288	100.0	100.0

Since there is no significant difference between the light glove and no glove at all, the injuries can be compared in the following way:

Hand Coverage	No Injury	Wrist-Hand Injury	Total
None, Light gloves	353	203	556
Medium and Heavy gloves and gauntlets	223	70	293
Total	576	273	849

$(\chi^2 = 13.44)$

In this way, the medium and heavy glove and gauntlet is seen to provide a highly significant level of protection from the typical hand injury.

TABLE 9.23.5. RIDER MOST SEVERE WRIST-HAND INJURY: INJURY SEVERITY BY TYPE OF HAND COVERAGE (OSIDs)

Hand Coverage	Count / Row Pct / Col Pct / Tot Pct	None 0	Minor 1	Moderate 2	Severe 3	Serious 4	Row Total
None		332 63.6 54.2 36.9	161 30.8 68.8 17.9	23 4.4 52.3 2.6	5 1.0 55.6 0.6	1 0.2 100.0 0.1	522 58.0
Light		21 61.8 3.4 2.3	11 32.4 4.7 1.2	2 5.9 4.5 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	34 3.8
Medium		98 76.6 16.0 10.9	23 18.0 9.8 2.6	6 4.7 13.6 0.7	1 0.8 11.1 0.1	0 0.0 0.0 0.0	128 14.2
Heavy		125 75.8 20.4 13.9	28 17.0 12.0 3.1	10 6.1 22.7 1.1	2 1.2 22.2 0.2	0 0.0 0.0 0.0	165 18.3
Unknown		36 70.6 5.9 4.0	11 21.6 4.7 1.2	3 5.9 6.8 0.3	1 2.0 11.1 0.1	0 0.0 0.0 0.0	51 5.7
	Column Total	612 68.0	234 26.0	44 4.9	9 1.0	1 0.0	900 100.0

9.24 Helmet Use Related to Hearing Critical Traffic Sounds

All riders involved in the 900 accidents were interviewed with the objective of determining any failure to detect traffic hazards by vision, hearing, etc. Also, the accident was carefully reconstructed to relate all pre-crash sounds in the chronology of the accident.

Hearing has little to do with the detection of traffic hazards: Vision predominates! No case of the 900 on-scene, in-depth investigations revealed a failure to detect critical traffic sounds, for helmeted or unhelmeted riders. Of course, there was no evidence then of any helmet obscuring or limiting the hearing of such traffic sounds.

As noted in the section on rider physiological impairment, a very small number of riders had partial or total hearing loss, and even these accidents showed no participation of hearing loss in accident causation.

9.25 Injuries Attributed to Safety Helmets

Only four injuries of the 861 head and neck injuries were attributed to the safety helmet, and all four were injury severity AIS = 1, or minor injuries. Two cases involved minor injury to nasal soft tissues by excessively large helmets rotating forward and contacting eyeglass frames. In both cases, the helmet attenuated head impact and protected against a threat level of AIS = 3 or 4.

A third helmet associated injury involved an AIS = 1 abrasion to the lower region of the jaw of the helmet user. The abrasion was due to a severe retention force on the chin strap when multiple impacts occurred on the helmet. The helmet fully attenuated the impacts and protected against critical or fatal threats, AIS = 5 or 6.

A fourth helmet associated injury was an AIS = 1 abrasion to the integument of the neck. The motorcycle rider over-braked for a traffic problem, skidded, and vaulted highside to land on the left shoulder and left side of the head. The resulting impact rotated the head and neck to the right and caused an impingement of the helmet edge on the soft tissues and skin. No other neck injury resulted; no head injury resulted. The helmet clearly protected against impact threat equivalent to AIS = 4 to 6.

Each one of these four cases showed that protection from possibly fatal injury was achieved, but with a small penalty of a "band-aid" type injury. Each one of these cases reinforced opinions regarding safety helmet effectiveness.

No other significant injuries were attributed in any way to the safety helmet equipment.

9.26 Rider Fatigue and Helmet Use

The question of fatigue, and the possibility of the helmet use contributing to fatigue, was given high priority in the accident data collection. The great part of these accidents occurred within the first hour of time riding; almost half occurred within the first six minutes! Fatigue--with or without a helmet--was difficult to expect with such short riding time before the accident.

The investigator was expected to evaluate the pre-crash time and rider action to determine if riding fatigue was a factor in accident causation. There was no evidence of riding fatigue in any of the accidents.

9.27 Safety Helmet Performance Related to FMVSS 218

Most of the helmets involved in these accidents were manufactured before 1974, and very few (20%) had been labeled as complying with FMVSS 218. Nevertheless, these helmets had other qualifications (Z-90, Snell, SHCA) and offered significant protection to the wearer, and even the simplest antique of head protection provided a major element of load spreading and impact attenuation to prevent or reduce injury. It was surprising indeed to see that a helmet of unknown origin and inexpensive manufacture could provide such adequate protection.

A great variety of shell and liner configurations were encountered, and very few protection failures were encountered. The only failures involved polycarbonate shells which had deteriorated at areas of high residual stress and stress concentration, due to stress crazing and cracking. In these cases, the shell suffered premature fracture at impact then failed to distribute the load to the liner or resulted in retention failures. The only precrash damage of significance was this crazing and cracking of polycarbonate shells, the damage to the styrofoam liners from sissy bars and mirrors was noticed but never contributed adversely in impact attenuation.

All helmets were examined and evaluated for all aspects of crash performance, and that performance then compared with basic elements of helmet qualification. The specific elements of helmet performance are related as follows:

Penetration resistance

The current requirement for penetration resistance seems to be severe and it is a realistic provision for approximately 1% of the helmet impacts. Limited cases of impact with sharp metal edges of automobiles or environment proved the need for some penetration test in the standard. However, in the actual accident conditions, a 90° metal edge was the much more common threat than the pointed surface of the FMVSS 218 standard penetrator. The current penetration test is severe for helmet compliance and the need for such strength and resistance should be more realistic if required by the standard. The penetration test of FMVSS 218 should be retained but modified to provide a more realistic penetration surface. The conical point penetrator of the current test should be replaced with a hardened steel edge approximately 1/8 inch thick and 1 inch long, in order to be representative of accident impact.

Retention performance

The present requirements of FMVSS 218 provide adequate strength and stiffness for the retention system and do not need change. No data or evidence in specific cases showed the need of the retention system to sustain more than 300 lbs. of load (with less than the limiting deflection of 1 in.). Also, there were no data or cases that showed any need for less strength or stiffness, only minor injuries were associated with severe retention forces and these minor injuries were unavoidable and acceptable under those circumstances. In addition, there were no cases which showed that the helmet retention system suffers great distress from dynamic or impulsive loading. In all cases where the helmet was of proper fit and fastened securely, the helmet was retained on the head for impact attenuation, and the dynamics of impact were no threat to helmet retention.

Although not a part of the accident data collected, the extreme cases of retention forces showed definite asymmetry, as compared with the symmetrical loading of the retention system test. It is estimated that those cases of asymmetrical loading would be approximated by a sideways component of test load of at least 25% of the system test load.

The accident cases where the helmet was not retained on the head showed that failure to fasten the retention system was the primary cause of helmet

loss. The typical D-ring system is a very simple device and failure to fasten such a simple system is very difficult to explain. In any case, the frequency of such problems is low and does not demand the same attention as the basic problem of helmet use.

Impact attenuation performance

Present requirements seem to provide adequate impact protection for the traffic collision impact conditions. The test impact by a 6 ft. drop height exceeds approximately 90% of the accident impacts, and the test which repeats impact at the same site with the same severity is not seen in the accident data. There is no doubt that the compliance tests which repeat impacts at the same site can be withstood only by very good helmets, and this is the only true justification for the repeated impact of the same severity.

A more realistic test procedure is that of the 1970 Snell qualification, where the second impact at the test site is much less severe than the original impact. In this 1970 Snell test, the second impact at the test site is 75% of the first impact and even this is far more severe than is seen in actual accident conditions. The accident data show that any second impact is no greater than approximately half of the most severe first impact at any location.

The impact acceleration limits specified for the tests of FMVSS 218 could not be evaluated quantitatively from this research. The limits of maximum headform acceleration and dwell time could not be evaluated because replication testing of all helmet impacts was not provided in the research data collection. Only a limited relation could be inferred: Full facial coverage helmets were shown to be most effective, many of the full facial coverage helmets were Snell 70 qualified, Snell 70 qualification specifies headform acceleration limits of 300 g's (compared to 400 g's for FMVSS 218) without regard for dwell time.

The impacting surface is predominantly flat pavement, so the flat anvil test is surely justified. The hemispherical anvil test realistically replicates most of the other accident impacts, except metal edges.

Coverage

Table 9.8.12 shows that 31.1% of all helmet impacts, occur below the test zones of coverage specified in FMVSS 218. Also, at least 11.5% of the most severe impacts occur below the current test zones. Of course, many other impacts were recorded on the face and head of unhelmeted riders in these same regions. The existence of these impacts demands that the zone of coverage and test for qualification must be lowered to guarantee impact attenuation within these areas. Two areas need to be accounted for in attempt to provide impact attenuation where it is not presently required. The lower part of the back of the head is not required to be covered or protected in the current standard, and the chin piece of full facial coverage helmets is not required to demonstrate any impact attenuation. The most appropriate advisory would be available from the Z-90 Committee of the American National Standards Institute, and it is recommended that this group be requested to study these data and provide recommendations for lowering of the test zone at the back of the head and provide a test procedure appropriate for the front impact attenuation applicable to full facial coverage helmets.

Visual space

No cases investigated showed any effect of the visual space interfering with vision or hazard detection, with 120° or 105° helmets. Visual space seems adequate under the present standard and no change is recommended.

Conditioning

All accident-involved helmets were being worn by the rider for sufficient time so that the interior was essentially at body temperature regardless of the ambient temperature. Consequently, cold soak provisions should apply to the exterior shell but allow the interior to be at body - or equivalent - temperature for test impacts.

The conditioning of the helmet by salt water immersion would be appropriate conditioning for the helmet continually worn on hot days, and the sweat-soaked accident helmet is typical of the hot day accident. It is recommended that the water immersion conditioning be modified to specify hot salt water immersion, with appropriate concentration, time and temperature.

Application of the standard

In past time, the FMVSS 218 standard applied to medium size helmets only, and hopefully that provision has been altered in recent time. All adult sizes that can be tested on the current size headform should be included in the standard. It is vital that ALL adult sizes of helmets offered for sale be required to comply with FMVSS 218 and be so labeled.

Another factor for consideration is that a few helmets which meet a particular performance standard much more severe than FMVSS 218 do not necessarily qualify for compliance, primarily because of the controversial dwell time limits of FMVSS 218. If a helmet configuration qualifies for current Snell Foundation approval, e.g., Snell 75, the helmet should be accepted as more than qualified for FMVSS 218 and could be DOT labeled.

9.28 Videotape and Movie Film Project

One project accomplished during this research was the development of a videotape and movie film which incorporated the major findings in the Status Report of Accident Data. The objective was to collect and present the most significant elements related to the effectiveness of safety helmets involved in motorcycle accidents.

With the cooperation of the United States Air Force Audio Visual Services Center at Norton Air Force Base, a script was prepared and a 22 minute videotape was produced on the subject, Motorcycle Safety-Helmet Effectiveness, DOT 9-001. The videotape was transferred to film to facilitate public use in educational facilities.

The videotape-film relates the research findings that safety helmets have an outstanding effect in preventing and reducing head and neck injuries, and contributes no adverse effects on hearing, vision, etc. The videotape-film describes the study area for this research and the methods for collection of the data.

Copies of the videotape-film are available through the Contract Technical Manager, Mr. Nicholas G. Tsongos, at nominal cost to private parties and without charge to public agencies and educational institutions.

10.0 EXPOSURE DATA

In order to distinguish those factors that are outstanding in accident events, accident characteristics, and accident causation, it is necessary to compare those features with the population-at-risk. The collection of exposure data needs certain constraints so that there is a special connection to the type of accident data. In this study, the location of the on-scene, in-depth accident cases was that location for the collection of exposure data. The following exposure data were collected at those accident locations on the same day-of-week, same time-of-day, and same environmental conditions. Those motorcycle riders at that location were interviewed, or photographed then contacted, to determine helmet use, trip plan, alcohol involvement, motorcycle type and size, experience, etc., so those same factors in the accident data could be evaluated.

Environmental Factors

10.1 Rider Trip Plan

Table 10.1.1 shows the distributions of trip origin and destination. As with the accident data, home and work predominate as the origin or destination of the trip.

The data on trip origin and destination are crosstabulated in Table 10.1.2. The riders for whom "work" is both origin and destination typically ride motorcycles as a part of their work, such as messengers, police and funeral escorts.

The length of the rider's intended trip, from origin to destination is tabulated in Table 10.1.3 (Appendix D.1). The median trip length was 8.7 miles, and the predominance of short trips is evident.

These data are summarized in Table 10.1.4. Here, the predominant trip length is between 5 and 50 miles. This is consistent with a median trip length of 8.7 miles.

10.2 Time Riding Motorcycle Before Interview

Riders responding to interviews reported having spent a median of 16 minutes riding from the origin of their trip to the time of interview. The most common response was "about five minutes" or one-tenth of an hour. These data are shown in Table 10.2.1.

TABLE 10.1.1. RIDER TRIP PLAN

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Origin				
Home	1.	281	12.2	42.8
Work	2.	185	8.0	28.2
Shopping	3.	51	2.2	7.8
Recreation	4.	67	2.9	10.2
Friends/Relatives	5.	46	2.0	7.0
Bar/Drinking Party	6.	2	0.1	0.3
School	7.	24	1.0	3.7
Unknown	8.	1654	71.3	MISSING
	TOTAL	2310	100.0	100.0
Destination				
Home	1.	185	8.0	28.0
Work	2.	159	6.9	24.1
Shopping	3.	70	3.0	10.6
Recreation	4.	150	6.5	22.7
Friends/Relatives	5.	60	2.6	9.1
Bar/Drinking Party	6.	1	0.0	0.2
School	7.	35	1.5	5.3
Unknown	8.	1650	71.4	MISSING
	TOTAL	2310	100.0	100.0

10.3 Median Traffic Flow

Traffic flow along the motorcycle and other vehicle paths of travel (at the scenes of multiple vehicle collisions) was measured at each exposure site. Only vehicles engaging in a pre-crash maneuver similar to that of the accident-involved vehicle(s) were counted. For example, if the case accident involved a motorcycle going east and a westbound car turning left in front of the motorcycle, then all eastbound traffic was counted in the motorcycle traffic flow, but only those westbound vehicles that turned left were counted on the other vehicle traffic flow. For this reason traffic flows appear higher on the motorcycle path. Vehicles were categorized as: Motorcycles (and Mopeds), Full and Intermediate Size Cars, Compacts, Subcompacts, Pick Up Trucks and Vans, Buses and Large Trucks, and Others (including bicycles, skateboards, roller skaters, etc.)

Median traffic flow in one hour (1/2 hour before and 1/2 hour after the reference accident time) along the motorcycle path of travel for each category is shown in Table 10.3.1.

TABLE 10.1.2. RIDER TRIP PLAN - ORIGIN AND DESTINATION

Origin	Count Row Pct Col Pct Tot Pct	Destination Home	Work	Shopping Errand	Recreation	Friends Relative	Bar Drinking Party	School	Unknown-Not Obs	N.A.	Row Total
Home		5 1.8 2.7 0.2	73 26.0 45.9 3.2	39 13.9 55.7 1.7	97 34.5 64.7 4.2	38 13.5 63.3 1.6	0 0.0 0.0 0.0	28 10.0 80.0 1.2	0 0.0 0.0 0.0	1 0.4 100.0 0.0	281 12.2
Work		79 42.7 42.7 3.4	69 37.3 43.4 3.0	16 8.6 22.9 0.7	14 7.6 9.3 0.6	5 2.7 8.3 0.2	0 0.0 0.0 0.0	2 1.1 5.7 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	185 8.0
Shopping Errand		31 60.8 16.8 1.3	9 17.6 5.7 0.4	6 11.8 8.6 0.3	1 2.0 0.7 0.0	4 7.8 6.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	51 2.2
Recreation		30 44.8 16.2 1.3	0 0.0 0.0 0.0	0 0.0 0.0 0.0	31 46.3 20.7 1.3	4 6.0 6.7 0.2	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 3.0 0.1 0.1	0 0.0 0.0 0.0	67 2.9
Friends Relative		22 47.8 11.9 1.0	1 2.2 0.6 0.0	8 17.4 11.4 0.3	6 13.0 4.0 0.3	7 15.2 11.7 0.3	0 0.0 0.0 0.0	2 4.3 5.7 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	46 2.0
Bar Drinking Party		1 50.0 0.5 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 50.0 100.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	2 0.1
School		16 66.7 8.6 0.7	3 12.5 1.9 0.1	1 4.2 1.4 0.0	0 0.0 0.0 0.0	2 8.3 3.3 0.1	0 0.0 0.0 0.0	2 8.3 5.7 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	24 1.0
Unknown-Not Obse		1 0.1 0.5 0.0	1 0.1 0.6 0.0	0 0.0 0.0 0.0	1 0.1 0.7 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	1 0.1 2.9 0.0	1644 99.8 99.7 71.2	0 0.0 0.0 0.0	1648 71.3
N.A.		0 0.0 0.0 0.0	3 50.0 1.9 0.1	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	0 0.0 0.0 0.0	3 50.0 0.2 0.1	0 0.0 0.0 0.0	6 0.3
	Column Table	185 8.0	159 6.9	70 3.0	150 6.5	60 2.6	1 0.0	35 1.5	1649 71.4	1 0.0	2310 100.0

TABLE 10.1.4. TRIP LENGTH SUMMARY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
0-1 Mile	1.	50	2.2	8.4	8.4
1-5 Miles	2.	167	7.2	27.9	36.3
5-50 Miles	3.	319	13.8	53.3	89.6
More than 50 Miles	4.	62	2.7	10.4	100.0
Unknown	8.	1712	74.1	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.2.1. TIME RIDING MOTORCYCLE BEFORE INTERVIEW

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Hours	0.0	23	1.0	3.9	3.9
	0.1	162	7.0	27.7	31.6
	0.2	102	4.4	17.5	49.1
	0.3	79	3.4	13.5	62.6
	0.4	19	0.8	3.3	65.9
	0.5	66	2.9	11.3	77.2
	0.6	8	0.3	1.4	78.6
	0.7	8	0.3	1.4	80.0
	0.8	12	0.5	2.1	82.1
	0.9	2	0.1	0.3	82.4
	1.0	30	1.3	5.1	87.5
	1.1	1	0.0	0.2	87.7
	1.3	1	0.0	0.2	87.9
	1.5	15	0.6	2.6	90.5
	2.0	18	0.8	3.1	93.6
	2.5	7	0.3	1.2	94.8
	3.0	12	0.5	2.1	96.9
	3.5	1	0.0	0.1	97.0
	4.0	7	0.3	1.2	98.2
	5.0	2	0.1	0.3	98.5
	5.2	1	0.0	0.2	98.7
	6.0	1	0.0	0.1	98.8
	7.0	1	0.0	0.2	99.0
	8.0	1	0.0	0.2	99.2
	9.8	1	0.0	0.1	99.3
	12.0	1	0.0	0.2	99.5
	15.0	1	0.0	0.2	99.7
	30.0	1	0.0	0.1	99.8
	45.4	1	0.0	0.2	100.0
Unknown	99.8	1726	74.7	MISSING	MISSING
	TOTAL	2310	100.0	100.0	

TABLE 10.3.1. MEDIAN TRAFFIC FLOW ON MOTORCYCLE PATH OF TRAVEL (ONE HOUR)

Vehicle Type	Median Hourly Flow	Relative Frequency (%)	Cumulative Frequency (%)
Motorcycles	1.4	0.5	0.5
Full Size Cars	131.0	45.7	46.2
Compact Cars	43.0	15.0	61.2
Subcompact Cars	70.3	24.5	85.7
Pickups and Vans	35.4	12.4	98.1
Trucks and Buses	5.0	1.7	99.9
Others	0.4	0.1	100.0
TOTAL	286.5	100.0	

Median traffic flow in one hour (1/2 hour before and 1/2 hour after the reference accident time) along the other vehicle path of travel for each category is shown in Table 10.3.2.

TABLE 10.3.2. MEDIAN TRAFFIC FLOW ON OTHER VEHICLE PATH OF TRAVEL (ONE HOUR)

Vehicle Type	Median Hourly Flow	Relative Frequency (%)	Cumulative Frequency (%)
Motorcycles	0.0	0.0	0.0
Full Size Cars	15.2	44.1	44.1
Compact Cars	5.7	16.5	60.6
Subcompact Cars	8.9	25.8	86.4
Pickups and Vans	4.2	12.2	98.6
Trucks and Buses	0.5	1.4	100.0
Others	0.0	0.0	100.0
TOTAL	34.5	100.0	

10.4 Weather

As in the accident data, clear weather conditions prevailed in the great majority of the exposure cases. Inclement weather accounted for 2.0% of the cases. These data are shown in Table 10.4.1. Cloudy and overcast conditions accounted for 18.6% of the exposure scenes and 14.2% of the accident cases. Rain and drizzle are equally represented in accident and exposure cases.

Temperatures taken at the time of exposures ranged from 35°F to 98°F with a median temperature of 68.3°F. The distribution of temperatures is shown in Table 10.4.2.

TABLE 10.4.1. WEATHER CONDITION AT EXPOSURE SITE

A. Motorcycle Rider Basis

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Clear	1.	1925	83.4	83.4	83.4
Rain	2.	3	0.1	0.1	83.5
Drizzle	3.	3	0.1	0.1	83.6
Cloudy or Partly Cloudy	7.	341	14.8	14.8	98.4
Overcast	8.	38	1.6	1.6	100.0
	TOTAL	2310	100.0	100.0	

B. Exposure Site Basis

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Clear	1.	401	79.4	79.4	79.4
Rain	2.	5	1.0	1.0	80.4
Drizzle	3.	5	1.0	1.0	81.4
Cloudy or Partly Cloudy	7.	76	15.0	15.0	96.4
Overcast	8.	18	3.6	3.6	100.0
	TOTAL	505	100.0	100.0	

TABLE 10.4.2. TEMPERATURE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
31-40°F	4.	16	0.7	0.7	0.7
41-50°F	5.	104	4.5	4.5	5.2
51-60°F	6.	372	16.1	16.1	21.3
61-70°F	7.	882	38.2	38.2	59.5
71-80°F	8.	615	26.6	26.6	86.1
81-90°F	9.	269	11.6	11.6	97.7
91-100°F	10.	52	2.3	2.3	100.0
	TOTAL	2310	100.0	100.0	

Vehicle Data

Motorcycles passing each exposure site were photographed whenever possible and later identified. Photographs were not always possible as in heavy traffic or night-freeway conditions. These photographs were analyzed for type, size, manufacturer, year, modifications, color and so on.

The motorcycles passing exposure sites were mostly street bikes (as opposed to choppers, enduros, etc.) with a displacement of 500cc or more. The motorcycles were usually newer - less than five years old; a large proportion had some sort of modification, and a majority (64.2%) had the headlamp on.

10.5 Motorcycle Size and Type

The distribution of engine displacements is shown in Table 10.5.1. Displacements of 50cc or less usually reflect mopeds, while very large displacements (1500cc and up) are indicative of 3-wheeled motorcycles with automobile engines. The median displacement is 625cc, while 750cc motorcycles account for nearly one-fourth of those identified.

Motorcycles were classified as in the accident data, except that mopeds and official police motorcycles were given their own categories. The great majority of the motorcycles were street bikes. Enduro-type motorcycles accounted for 5.1% of the exposure cases, but more than twice that number of accident cases. Semi-choppers are similarly over-represented in accident cases as shown in Table 10.5.2.

10.6 Manufacturer of Motorcycles

Motorcycle manufacturers are listed in Table 10.6.1.

10.7 Year of Manufacture, or Model Year

The model year or year of manufacture was determined from examination of the motorcycle or photographs. The distribution of years is shown in Table 10.7.1.

10.8 Predominating Color of the Motorcycle

The distribution of motorcycle predominating color is shown in Table 10.8.1.

10.9 Motorcycle Modifications

Motorcycles passing each exposure site were evaluated for modifications to the front suspension, handlebars, seat, rear wheel and exhaust system, or the addition of crash bars, a sissybar, fairing and/or windshield. Approximately 92% of the motorcycles passing exposure sites were thus evaluated; of those:

TABLE 10.5.1. MOTORCYCLE MODEL SIZE OR ENGINE DISPLACEMENT, CC.

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Size or Displacement, cc	49.	1	0.0	0.0	0.0
	50.	90	3.9	4.3	4.4
	60.	1	0.0	0.0	4.4
	70.	3	0.1	0.1	4.6
	75.	1	0.0	0.0	4.6
	80.	3	0.1	0.1	4.8
	90.	22	1.0	1.1	5.8
	100.	20	0.9	1.0	6.8
	125.	36	1.6	1.7	8.5
	150.	1	0.0	0.0	8.6
	160.	2	0.1	0.1	8.7
	175.	38	1.6	1.8	10.5
	185.	14	0.6	0.7	11.2
	200.	40	1.7	1.9	13.1
	250.	42	1.8	2.0	15.1
	300.	1	0.0	0.0	15.2
	350.	118	5.1	5.7	20.8
	360.	79	3.4	3.8	24.6
	380.	7	0.3	0.3	25.0
	400	173	7.5	8.3	33.3
	450.	45	1.9	2.2	35.5
	500.	107	4.6	5.1	40.6
	550.	128	5.5	6.2	46.8
	600.	5	0.2	0.2	47.0
Median = 625cc	650.	123	5.3	5.9	52.9
	750.	490	21.2	23.6	76.5
	800.	1	0.0	0.0	76.6
	850.	21	0.9	1.0	77.6
	900.	45	1.9	2.2	79.7
	1000.	214	9.3	10.3	90.0
	1100.	14	0.6	0.7	90.7
	1200.	186	8.1	9.0	99.7
	1340.	1	0.0	0.0	99.7
	1500.	1	0.0	0.0	99.8
	1600.	1	0.0	0.0	99.8
	1650.	2	0.1	0.1	99.9
	1700.	1	0.0	0.0	100.0
Unknown	9998.	233	10.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.5.2. MOTORCYCLE TYPE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Street OEM	1.	1764	76.4	76.4
Dirt	2.	14	0.6	0.6
Enduro	3.	118	5.1	5.1
Semi-Chopper	4.	88	3.8	3.8
Chopper	5.	115	5.0	5.0
Cafe Racer	6.	11	0.5	0.5
Trike	7.	11	0.5	0.5
Moped	8.	58	4.2	4.2
Police Motorcycle	9.	91	3.9	3.9
	TOTAL	2310	100.0	100.0

(1) 10.6% had modifications to the front suspension

(2) 27.3% had modified exhaust systems

(3) 14.1% had a modified rear wheel

(4) 18.1% were equipped with crash bars

(5) 29.8% had a sissybar

(6) 23.1% had a modified seat

(7) 19.5% were equipped with a windshield (with or without fairing)

(8) 12.3% were equipped with a fairing

(9) 24.8% had modified handlebars

10.10 Headlamp Usage

Headlamp use was determined for 88.1% of the motorcycles passing exposure sites. Of those for which headlamp function was determined, 72.8% had the headlamp on, as shown in Table 10.10.1.

However, 1978 & 1979 model year street motorcycles are equipped with a headlamp that is operating automatically when the ignition switch is on. Most 1977 and earlier models have the headlamp use determined by headlamp switch operated as a matter of rider choice, of course, a few pre-1978 models, such as the 1977 Honda CB750K, were equipped with such an "automatic-on" function. These were present in the accident data collection and account for a portion of those data. Non-operation of the headlamp in 1978 and 1979 models can represent some failure in the electrical system or the intentional defeating of the "automatic-on"

TABLE 10.6.1. MOTORCYCLE MANUFACTURER

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Ariel	2.	3	0.1	0.1
BMW	3.	60	2.6	2.8
BSA	4.	6	0.3	0.3
Bridgestone	5.	1	0.0	0.0
Bultaco	6.	1	0.0	0.0
Cushman	11.	6	0.3	0.3
Ducati	14.	2	0.1	0.1
Harley-Davidson	20.	241	10.4	11.4
Hercules	21.	1	0.0	0.0
Honda	23.	1011	43.8	47.7
Indian	25.	1	0.0	0.0
Kawasaki	28.	223	9.7	10.5
Maico	31.	1	0.0	0.0
Matchless	32.	1	0.0	0.0
Moto Guzzi	35.	31	1.3	1.5
Norton	40.	8	0.3	0.4
Puch	44.	14	0.6	0.7
Suzuki	54.	154	6.7	7.3
Triumph	55.	44	1.9	2.1
H-D Trike	56.	3	0.1	0.1
Trike, VW Engine	57.	4	0.2	0.2
Vespa	60.	18	0.8	0.8
Yamaha	62.	243	10.5	11.5
Motobecane	65.	39	1.7	1.8
Beta	67.	1	0.0	0.0
Other	97.	2	0.1	0.1
Unknown	98.	191	8.3	MISSING
	TOTAL	2310	100.0	100.0

TABLE 10.7.1. MOTORCYCLE MODEL YEAR

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
19__	41.	2	0.1	0.1	0.1
	48.	1	0.0	0.1	0.2
	50.	2	0.1	0.1	0.3
	53.	1	0.0	0.1	0.4
	56.	1	0.0	0.1	0.4
	57.	1	0.0	0.1	0.5
	58.	1	0.0	0.1	0.5
	59.	1	0.0	0.1	0.6
	60.	1	0.0	0.1	0.6
	61.	1	0.0	0.1	0.7
	62.	4	0.2	0.2	0.9
	64.	1	0.0	0.1	1.0
	65.	6	0.3	0.4	1.3
	66.	6	0.3	0.4	1.7
	67.	5	0.2	0.3	2.0
	68.	9	0.4	0.5	2.5
	69.	19	0.8	1.1	3.6
	70.	41	1.8	2.4	6.0
	71.	45	1.9	2.6	8.7
	72.	80	3.5	4.7	13.4
	73.	94	4.1	5.5	18.9
	74.	113	4.9	6.6	25.5
	75.	231	10.0	13.5	39.0
	76.	213	9.2	12.5	51.4
	77.	300	13.0	17.5	69.1
	78.	472	20.4	27.7	96.8
	79.	53	2.3	3.1	100.0
Unknown	98.	604	26.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.8.1. MOTORCYCLE PREDOMINATING COLOR

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
White	1.	142	6.1	7.2	7.2
Yellow	2.	69	3.0	3.5	10.7
Orange	3.	115	5.0	5.8	16.6
Black	4.	489	21.2	24.8	41.4
Brown	5.	96	4.2	4.9	46.3
Blue	6.	335	14.5	17.0	63.3
Red	7.	414	17.9	21.0	84.3
Purple	8.	31	1.3	1.6	85.9
Green	9.	115	5.0	5.8	91.7
Silver-Gray	10.	97	4.2	4.9	96.6
Gold	11.	48	2.1	2.4	99.1
Chrome-Metal Flake	12.	4	0.2	0.2	99.3
Others	97.	14	0.6	0.7	100.0
Unknown	98.	341	14.8	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.10.1. MOTORCYCLE HEADLAMP USE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
On	1.	1483	64.2	72.8	72.8
Off	2.	553	23.9	27.2	100.0
Unknown	8.	274	11.9	MISSING	100.0
	TOTAL	2310	100.0	100.0	

system by the rider. For these reasons, headlamp use was distinguished for these 1978-1979 models. Table 10.10.2, summarizes data to show that 1978-1979 models accounted for 30.8% of those for which model year was identified.

Table 10.10.3 provides a crosstabulation to show headlamp usage for all vehicle data collected: Daylight, Dusk-Dawn and Night are combined. The pre-1978 models were determined to have the headlamp on in 64% of the observations, while 1978-1979 models had the headlamp on in 84.4%.

Of course, headlamp usage would be expected to vary with ambient lighting, being higher at night and lower in daytime. For this reason, separate cross-tabulations of model year and headlamp use were made for each of the three major ambient conditions, daylight, dusk-dawn and night. Table 10.10.4 shows the distribution of motorcycle observations under the various ambient light conditions. "Night-Lighted" and "Night-Unlighted" have been collapsed here into a single "Night-Time" category.

TABLE 10.10.2. MOTORCYCLE MODEL YEAR CATEGORY:
PRE-1978, 1978 & 1979

Category Label	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Pre-1978	1182	51.2	69.2
1978 & 1979	525	22.7	30.8
Unknown	603	26.1	MISSING
TOTAL	2310	100.0	100.0

TABLE 10.10.3. HEADLAMP USE BY MODEL YEAR
ALL AMBIENT LIGHTING CONDITIONS

Model Year	COUNT ROW PCT COL PCT TOT PCT	Headlamp Use			
		On	Off	Unknown	Total
Pre-1978		757 64.0 51.0 32.8	352 29.8 63.7 15.2	73 6.2 26.6 3.2	1182 51.2
1978-1979		443 84.4 29.9 19.2	51 9.7 9.2 2.2	31 5.9 11.3 1.3	525 22.7
Unknown		283 46.9 19.1 12.3	150 24.9 27.1 6.5	170 28.2 62.0 7.4	603 26.1
	Column Total	1483 64.2	553 23.9	274 11.9	2310 100.0

Daylight Headlamp Use

Of 1671 motorcycles passing exposure sites in daylight, model year was determined for 79.9%. Approximately one-fourth of the total were identified as 1978-1979 models as shown in Table 10.10.5. Headlamp use was identified for these motorcycles; Table 10.10.6 shows that at least 60.2% had the headlamp on in daylight.

These data are crosstabulated to show daylight headlamp use or non-use for 1978-1979 model years versus earlier years. Table 10.10.7 shows that at least 59.4% of the pre-1978 motorcycles had the headlamp on in daylight while at least 82.3% of the 1978-1979 motorcycles (with the automatic-on headlamp function) had the headlamp operating.

TABLE 10.10.4. AMBIENT LIGHTING CONDITIONS

A. At Exposure Sites:

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Daylight	1.	370	73.3
Dusk-Dawn	2.	40	7.9
Night	3,4.	95	18.8
	TOTAL	505	100.0

B. Tabulation by Motorcycles:

Category Label	Code	Absolute Frequency	Relative Frequency (%)
Daylight	1.	1671	72.3
Dusk-Dawn	2.	307	13.3
Night	3,4.	332	14.4
	TOTAL	2310	100.0

TABLE 10.10.5. MOTORCYCLE YEAR CATEGORY: DAYLIGHT EXPOSURE DATA

Motorcycle Year	Absolute Frequency	Relative Frequency (%)
Pre-1978	911	54.5
1978-1979	424	25.4
Unknown	336	20.1
TOTAL	1671	100.0

TABLE 10.10.6. HEADLAMP USE IN DAYLIGHT

Headlamp Use	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
On	1006	60.2	68.5
Off	463	27.7	31.5
Unknown	202	12.1	MISSING
TOTAL	1671	100.0	100.0

TABLE 10.10.7. DAYLIGHT HEADLAMP USE BY MODEL YEAR CATEGORY

Model Year	COUNT ROW PCT COL PCT TOT PCT	Headlamp Use On	Off	Unknown	Total
Pre-1978		541 59.4 53.8 32.4	311 34.1 67.2 18.6	59 6.5 29.2 3.5	911 54.5
1978-1979		349 82.3 34.7 20.9	47 11.1 10.2 2.8	28 6.6 13.9 1.7	424 25.4
Unknown		116 34.5 11.5 6.9	105 31.3 22.7 6.3	115 34.2 56.9 6.9	336 20.1
	Column Total	1006 60.2	463 27.7	202 12.1	1671 100.0

Dusk-Dawn Headlamp Use

Model year and headlamp use were identified for the 307 motorcycles that passed exposure sites in dusk-dawn lighting conditions. Table 10.10.8 shows the breakdown of model year for these motorcycles.

TABLE 10.10.8. MOTORCYCLE MODEL YEAR CATEGORY:
DUSK-DAWN EXPOSURE DATA

Motorcycle Year	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Pre-1978	135	44.0	73.4
1978-1979	48	15.6	26.6
Unknown	124	40.4	MISSING
TOTAL	307	100.0	100.0

Headlamp use in dusk-dawn lighting is shown in Table 10.10.9. Surprisingly, the headlamp was identified as being on only slightly more than in daytime.

The dusk-dawn data for headlamp use by motorcycle year are crosstabulated in Table 10.10.10. These data show that pre-1978 models had the headlamp on 68.9% of the time; for 1978-1979 models the headlamp was on 87.5% of the time.

TABLE 10.10.9. DUSK-DAWN HEADLAMP USE

Headlamp Use	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
On	188	61.2	71.2
Off	76	24.8	28.8
Unknown	43	14.0	MISSING
TOTAL	307	100.0	100.0

TABLE 10.10.10. DUSK-DAWN HEADLAMP USE BY MODEL YEAR CATEGORY

Model Year	COUNT ROW PCT COL PCT TOT PCT	Headlamp Use			
		On	Off	Unknown	Total
Pre-1978		93 68.9 49.5 30.3	31 23.0 40.8 10.1	11 8.1 25.6 3.6	135 44.0
1978-1979		42 87.5 22.3 13.7	3 6.3 3.9 1.0	3 6.3 7.0 1.0	48 15.6
Unknown		53 42.7 28.2 17.3	42 33.9 55.3 13.7	29 23.4 67.4 9.4	124 40.4
	Column Total	188 61.2	76 24.8	43 14.0	307 100.0

Headlamp Use at Night

A total of 332 motorcycles passed exposure sites at night. The model year was identified for 189 (56.9%); of those identified 28% were 1978-1979 models, as shown in Table 10.10.11.

Of the 332 motorcycles passing exposure sites at night, headlamp function was identified for 303 (92.1%). Of these, the headlamp was on 95.4% of the time. The data are shown in Table 10.10.12.

The data from these tables were crosstabulated to separate headlamp use by model year for night exposures. This data appears in Table 10.10.13, which shows 98.1% headlamp use for 1978-1979 models and 90.4% use for the pre-1978 years. Of the pre-1978 models, 1 in 14 had the headlamp off at night, while only 1 in 53 of the 1978-1979 models was so identified.

TABLE 10.10.11. MOTORCYCLE MODEL YEAR CATEGORY: NIGHT EXPOSURE DATA

Motorcycle Year	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Pre-1978	136	41.0	72.0
1978-1979	53	16.0	28.0
Unknown	143	43.1	MISSING
TOTAL	332	100.0	100.0

TABLE 10.10.12. HEADLAMP USE AT NIGHT

Headlamp Use	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
On	289	87.0	95.4
Off	14	4.2	4.6
Unknown	29	8.7	MISSING
TOTAL	332	100.0	100.0

TABLE 10.10.13. NIGHT HEADLAMP USE BY MODEL YEAR CATEGORY

Model Year	COUNT ROW PCT COL PCT TOT PCT	Headlamp Use			Total
		On	Off	Unknown	
Pre-1978		123 90.4 42.6 37.0	10 7.4 71.4 3.0	3 2.2 10.3 0.9	136 41.0
1978-1979		52 98.1 18.0 15.7	1 1.9 7.1 0.3	0 0.0 0.0 0.0	53 16.0
Unknown		114 79.7 39.4 34.3	3 2.1 21.4 0.9	26 18.2 89.7 7.8	143 43.1
	Column Total	289 87.0	14 4.2	29 8.7	332 100.0

Summary of Headlamp and Illumination Data

The exposure data suggest a relatively high level of headlamp use: Headlamp use and model year were identified for 1603 motorcycles, of which 1200 (74.9%) had the headlamp on. Even for model years where headlamp use is largely a matter of rider choice the headlamp was on in at least 60.2% of the observations.

Human Factors

10.11 Motorcycle Rider Age

Ages of riders were determined for 27% of the riders passing exposure sites. The ages ranged from 12-73 years, and the median age was 26.7 years. The largest portion (70%) of riders fell in the 18-34 age bracket. These data are shown in Table 10.11.1.

10.12 Motorcycle Rider Sex, Marital Status, Children

Rider sex was determined from photos and interviews for 90% of those passing exposure sites. Females accounted for 1.5%. The distribution is shown in Table 10.12.1.

The data on marital status of riders passing exposure sites is shown in Table 10.12.2. The number of children reported by these riders is shown in Table 10.12.3.

10.13 Motorcycle Rider Height and Weight

Rider height was determined in 27.3% of the exposure cases. The median height in these cases was 69.4 inches. The distribution is shown in Table 10.13.1 (Appendix).

Rider weights in the exposure study were very similar to the accident data; the median weight in exposure cases was 159.9 pounds. The data are shown in Table 10.13.2 (Appendix D.1).

10.14 Motorcycle Rider Occupation and Education

Riders interviewed in the exposure study were employed primarily in crafts, service and professional occupations; another large group was primarily students. The distribution is shown in Table 10.14.1.

The highest level of formal education attained by the riders in the exposure study was typically partial college education; however, only 17.6% had completed college. The median level of education was approximately 1/2 year of college. The distribution is shown in Table 10.14.2.

TABLE 10.11.1. MOTORCYCLE RIDER AGE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Age, years	12.	1	0.0	0.2	0.2
	13.	2	0.1	0.3	0.5
	14.	2	0.1	0.3	0.8
	16.	11	0.5	1.8	2.6
	17.	17	0.7	2.7	5.3
	18.	25	1.1	4.0	9.3
	19.	36	1.6	5.8	15.1
	20.	19	0.8	3.0	18.1
	21.	30	1.3	4.8	22.9
	22.	27	1.2	4.3	27.2
	23.	39	1.7	6.3	33.5
	24.	29	1.3	4.6	38.1
	25.	32	1.4	5.1	43.3
	26.	26	1.1	4.2	47.4
	27.	22	1.0	3.5	51.0
	28.	40	1.7	6.4	57.4
	29.	18	0.8	2.9	60.3
	30.	19	0.8	3.0	63.3
	31.	29	1.3	4.6	67.9
	32.	25	1.1	4.0	72.0
	33.	25	1.1	4.0	76.0
	34.	21	0.9	3.4	79.3
	35.	6	0.3	1.0	80.3
	36.	13	0.6	2.1	82.4
	37.	18	0.8	2.9	85.3
	38.	5	0.2	0.8	86.1
	39.	10	0.4	1.6	87.7
	40.	10	0.4	1.6	89.3
	41.	4	0.2	0.6	89.9
	42.	8	0.3	1.3	91.2
	43.	3	0.1	0.5	91.7
	44.	6	0.3	1.0	92.6
	45.	2	0.1	0.3	92.9
	46.	3	0.1	0.5	93.4
	47.	13	0.6	2.1	95.5
	48.	3	0.1	0.5	96.0
	49	3	0.1	0.5	96.5
	51.	1	0.0	0.2	96.6
	52.	2	0.1	0.3	97.0
	53.	5	0.2	0.8	97.8
	55.	2	0.1	0.3	98.1
	56.	1	0.0	0.2	98.2
	57.	2	0.1	0.3	98.6
	59.	1	0.0	0.2	98.7
	61.	2	0.1	0.3	99.0
	64.	2	0.1	0.3	99.4
	65.	1	0.0	0.2	99.5
	68.	1	0.0	0.2	99.7
	71.	1	0.0	0.2	99.8
	73.	1	0.0	0.2	100.0
Unknown	98.	1686	73.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.12.1. MOTORCYCLE RIDER SEX

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Male	1.	2045	88.5	98.4	98.4
Female	2.	32	1.4	1.5	100.0
Not Observed	3.	1	0.0	0.0	100.0
Unknown	8.	232	10.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.12.2. RIDER MARITAL STATUS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Single	1.	373	16.1	59.6
Married	2.	188	8.1	30.0
Separated	3.	16	0.7	2.6
Divorced	4.	34	1.5	5.4
Widowed	5.	4	0.2	0.6
Cohabitating	6.	11	0.5	1.8
Not Observed	8.	1684	72.9	MISSING
	TOTAL	2310	100.0	100.0

TABLE 10.12.3. NUMBER OF CHILDREN

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Number of children	0.	418	18.1	67.4
	1.	69	3.0	11.1
	2.	80	3.5	12.9
	3.	29	1.3	4.7
	4.	14	0.6	2.3
	5.	8	0.3	1.3
	6.	1	0.0	0.2
Seven Or More	7.	1	0.0	0.2
Not Observed	8.	1690	73.2	MISSING
	TOTAL	2310	100.0	100.0

TABLE 10.14.1. MOTORCYCLE RIDER OCCUPATION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Professional	1.	102	4.4	15.0
Administrator	2.	42	1.8	6.2
Sales Worker	3.	39	1.7	5.8
Clerical	4.	44	1.9	6.5
Craftsman	5.	148	6.4	21.8
Operative	6.	15	0.6	2.2
Transport Operative	7.	19	0.8	2.8
Laborer	8.	66	2.9	9.7
Farm Laborer	10.	1	0.0	0.1
Service Worker	11.	83	3.6	12.2
Household Worker	12.	1	0.0	0.1
Student	14.	89	3.9	13.1
Military	15.	3	0.1	0.4
Retired	16.	7	0.3	1.0
Unemployed-over 1 Mo.	17.	19	0.8	2.8
Unknown	98.	1632	70.6	MISSING
	TOTAL	2310	100.0	100.0

TABLE 10.14.2. MOTORCYCLE RIDER EDUCATION STATUS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)
Grad School-Professional	1.	26	1.1	4.2
College-University	2.	83	3.6	13.4
Partial College	3.	237	10.3	38.2
High School	4.	165	7.1	26.6
Partial High School	5.	52	4.0	14.8
Jr. High or Grammar School	6.	14	0.6	2.3
Less Than 7 Years	7.	4	0.2	0.6
Unknown	8.	1689	73.1	MISSING
	TOTAL	2310	100.0	100.0

10.15 Motorcycle Rider License Qualification

Riders interviewed at exposure sites or responding to a follow-up questionnaire reported having the required Class 4 endorsement or a permit for motorcycle operation in 77.4% of the cases. This is shown in Table 10.15.1. Of those who did not have a license and the motorcycle endorsement, one third had a motorcycle permit (which restricts riding to daylight operation without a passenger), as shown in Table 10.15.2.

TABLE 10.15.1. DRIVER LICENSE CLASS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
No License	0.	33	1.4	4.9	4.9
Class 1	1.	14	0.6	2.1	6.9
Class 2	2.	9	0.4	1.3	8.3
Class 3	3.	97	4.2	14.3	22.6
Class 4 or Equiv	4.	508	22.0	74.9	97.5
Learner Permit	5.	17	0.7	2.5	100.0
Unknown	8.	1632	70.6	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.15.2. DID OPERATOR HAVE MOTORCYCLE PERMIT?
(If No Class 4 License)

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes	1.	44	1.9	33.3	33.3
No	2.	88	3.8	66.7	100.0
Not Observed	8.	1642	71.1	MISSING	100.0
N.A.	9.	536	23.2	MISSING	100.0
	TOTAL	2310	100.0	100.0	

The majority of riders held California Drivers Licenses; no other state contributed more than 1% to the riders interviewed. This is shown in Table 10.15.3 (Appendix D.1).

10.16 Motorcycle Rider Traffic Violation and Accident Experience

Riders responding to exposure data collection queries reported a low level of violation experience with police agencies. Over half reported having no citations for moving violations in the previous two years. Data are shown in Table 10.16.1.

TABLE 10.16.1. RIDER MOVING VIOLATIONS IN LAST 2 YEARS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	306	13.2	52.2	52.2
	1.	116	5.0	19.8	72.0
	2.	70	3.0	11.9	84.0
	3.	39	1.7	6.7	90.6
	4.	18	0.8	3.1	93.7
	5.	12	0.5	2.0	95.7
	6.	8	0.3	1.4	97.1
More Than Six	7.	17	0.7	2.9	100.0
Unknown	8.	1724	74.6	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Similarly, exposure study participants had a low level of accident involvement in the two previous years, as shown in Table 10.16.2.

TABLE 10.16.2. RIDER TRAFFIC ACCIDENTS IN LAST 2 YEARS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	440	19.0	76.0	76.0
	1.	106	4.6	18.3	94.3
	2.	23	1.0	4.0	98.3
	3.	7	0.3	1.2	99.5
	4.	1	0.0	0.2	99.7
	6.	1	0.0	0.2	99.8
More Than Six	7.	1	0.0	0.2	100.0
Unknown	8.	1731	74.9	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.17 Motorcycle Rider Training Experience

As in the accident cases, riders in the exposure study show a preponderance of informal training, most being self-taught or learning from friends or family. This type of informal learning experience accounts for 84.3% of the participants in the exposure study. This figure re-emphasizes the haphazard way in which accurate information is transmitted to the novice rider. Conversations with riders at exposure sites were often littered in inaccurate information the rider had acquired in his "training." Most often, inaccurate information related to helmets, collision avoidance techniques and riding strategies.

If one were to believe many riders in the exposure study, use of the front brake will surely throw the rider right over the handlebars, while "laying it down" is the most effective way to avoid an accident. Such thinking is common when critical information is conveyed poorly or not at all.

The distribution of rider training backgrounds is shown in Table 10.17.1.

TABLE 10.17.1. RIDER MOTORCYCLE TRAINING EXPERIENCE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Self Taught	0.	382	16.5	57.0	57.0
Friends-Family	1.	183	7.9	27.3	84.3
School-Club	2.	68	2.9	10.1	94.5
Formal-AMA AFM FIM	3.	36	1.6	5.4	99.9
Others	7.	1	0.0	0.1	100.0
Unknown	8.	1640	71.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.18 Motorcycle Rider Dirt Bike Experience

In the exposure study responding riders were classified as having no dirt riding experience (which included "once or twice on a friend's dirt bike"), moderate trail riding experience, or frequent or competition dirt riding experience. A majority, 58.5%, reported having moderate to extensive dirt riding experience. The data are shown in Table 10.18.1.

TABLE 10.18.1. RIDER OFF-ROAD DIRT BIKE EXPERIENCE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	259	11.2	41.5	41.5
Some Trail Bike Riding	1.	232	10.0	37.2	78.7
Enduro-MX-Desert	2.	133	5.8	21.3	100.0
Unknown	8.	1685	72.9	MISSING	100.0
N.A.	9.	1	0.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.19 Motorcycle Rider Street Bike Experience

For the majority of responding riders in the exposure study, the motorcycle appears to be a major or sole form of transportation: It is ridden five or more days a week by 78.3% of those interviewed. The data are shown in Table 10.19.1.

TABLE 10.19.1. DAYS PER WEEK MOTORCYCLE RIDDEN

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
	0.	3	0.1	0.5	0.5
	1.	27	1.2	4.1	4.6
	2.	39	1.7	6.0	10.5
	3.	45	1.9	6.9	17.4
	4.	29	1.3	4.4	21.8
	5.	134	5.8	20.5	42.3
	6.	58	2.5	8.9	51.1
	7.	320	13.9	48.9	100.0
Unknown	8.	1655	71.7	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Riders participating in the exposure study reported having considerable motorcycle riding experience, the most frequent response being more than eight years. The median experience reported was 47.4 months. The data are shown in Table 10.19.2 (Appendix D.1).

Riders responding to exposure data collectors reported a median of nine months experience on the motorcycle they were riding at the time they were observed/interviewed. The data are shown in Table 10.19.3 (Appendix D.1).

10.20 Motorcycle Rider Familiarity with the Roadway

Nearly half the riders interviewed reported travelling the involved roadway at least daily (for police motorcyclists the figure was often hourly rather than daily). Over two-thirds, 68.8%, reported travelling the involved roadway at least weekly, indicating a high level of familiarity with the area. These data are shown in Table 10.20.1.

TABLE 10.20.1. NUMBER OF TIMES ON INVOLVED ROADWAY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Never Before	0.	48	2.1	7.4	7.4
Daily	1.	312	13.5	48.1	55.6
1-4 Times per Week	2.	134	5.8	20.7	76.2
1-3 Times per Month	3.	83	3.6	12.8	89.0
1-2 Times per Quarter	4.	24	1.0	3.7	92.7
1-3 Times per Year	5.	38	1.6	5.9	98.6
Less than Annually	6.	9	0.4	1.4	100.0
Unknown	8.	1662	71.9	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.21 Motorcycle Rider Hand Preference

The data on hand preference are shown in Table 10.21.1. This is comparable to the accident data although more than twice as many exposure study riders reported being ambidextrous.

TABLE 10.21.1. MOTORCYCLE RIDER HAND PREFERENCE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Right	1.	502	21.7	80.7	80.7
Left	2.	69	3.0	11.1	91.8
Ambidextrous	3.	51	2.2	8.2	100.0
Unknown	8.	1688	73.1	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.22 Motorcycle Rider Alcohol and Drug Involvement

Approximately one rider in six interviewed in the exposure study reported at least some alcohol or drug involvement. This was principally mild alcohol use or marijuana use (alcohol use was undoubtedly the ubiquitous "couple of beers"). Drug use was typically on a non-prescription basis.

Alcohol and drug use may have been somewhat higher than reported here. Questions about use of intoxicants came late in the interview, when the interviewer had had an opportunity to establish some rapport with the rider and reduce any perceived threat of being penalized for admitting to use of intoxicants. However, as interviewers might still present an unfamiliar and potentially official threat, some riders may have been reluctant to admit to alcohol or drug use. Data on drug and alcohol use are shown in Table 10.22.1.

TABLE 10.22.1. RIDER ALCOHOL-DRUG IMPAIRMENT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
HBD-Not Under Influence	1.	47	2.0	8.0	8.0
HBD-Under Influence	2.	4	0.2	0.7	8.7
HBD-Impairment Unknown	3.	9	0.4	1.5	10.2
Under Drug Influence	4.	5	0.2	0.8	11.0
Combination	5.	4	0.2	0.7	11.7
Unknown	8.	1725	74.7	MISSING	MISSING
No Alcohol or Drug Involvement	9.	516	22.3	88.2	100.0
	TOTAL	2310	100.0	100.0	

Data on estimated blood alcohol levels are shown in Table 10.22.2. Levels were determined by calculations based upon the amount consumed, elapsed time and the rider's weight.

TABLE 10.22.2. RIDER BLOOD ALCOHOL LEVEL-ESTIMATED

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Hundredths of 1%	0.	538	23.3	93.9	93.9
	1.	10	0.4	1.7	95.6
	2.	7	0.3	1.2	96.9
	3.	3	0.1	0.5	97.4
	4.	11	0.5	1.9	99.3
	5.	1	0.0	0.2	99.5
	7.	1	0.0	0.2	99.7
	10.	1	0.0	0.2	99.8
	11.	1	0.0	0.2	100.0
Not Observed	98.	1721	74.5	MISSING	100.0
Not Applicable	99.	16	0.7	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Data illustrating prescription and non-prescription drug use are shown in Table 10.22.3.

TABLE 10.22.3. RIDER USE OF DRUGS OTHER THAN ALCOHOL
PRESCRIPTION/NON-PRESCRIPTION STATUS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	573	24.8	24.8	24.8
Prescription	1.	12	0.5	0.5	25.3
Non-Prescription	2.	40	1.7	1.7	27.1
Not Observed	8.	1684	72.9	72.9	100.0
N.A.	9.	1	0.0	0.0	100.0
	TOTAL	2310	100.0	100.0	

Table 10.22.4 classifies and tabulates the drugs reported used by riders interviewed in the exposure study.

10.23 Motorcycle Rider Permanent Physiological Impairment

Permanent disabilities were reported by very few riders, as shown in Table 10.23.1.

TABLE 10.22.4. RIDER USE OF DRUGS OTHER THAN ALCOHOL DRUG CATEGORY

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	558	24.2	90.0	90.0
Marijuana	1.	49	2.1	7.9	97.9
Stimulants	2.	2	0.1	0.3	98.2
Depressants	3.	7	0.3	1.1	99.4
Antihistamines-Depress.	5.	2	0.1	0.3	99.7
Antihistamines-Stimuls.	6.	1	0.0	0.2	99.8
Multiples-Incl. Alcohol	7.	1	0.0	0.2	100.0
Not Observed	8.	1689	73.1	MISSING	100.0
N.A.	9	1	0.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.23.1. RIDER PERMANENT PHYSIOLOGICAL IMPAIRMENT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	2271	98.3	98.3	98.3
Arthritis	1.	1	0.0	0.0	98.4
Diabetes	2.	5	0.2	0.2	98.6
Cardio-Vascular	4.	2	0.1	0.1	98.7
Vision	5.	8	0.3	0.3	99.0
Hearing	6.	8	0.3	0.3	99.4
Others	7.	9	0.4	0.4	99.7
Paraplegic, Amputees	8.	6	0.3	0.3	100.0
	TOTAL	2310	100.0	100.0	

Transient physical problems were reported infrequently, in about 10% of the riders interviewed. The data are shown in Table 10.23.2.

10.24 Motorcycle Rider Tattoos

The majority of riders interviewed claimed to have no tattoos, and these data are shown in Table 10.24.1.

10.25 Motorcycle Rider Attention to Driving Task

Wherever possible an attempt was made to evaluate where the rider's attention was directed when passing the exposure site. Those data are shown in Table 10.25.1.

TABLE 10.23.2. RIDER TRANSIENT PHYSIOLOGICAL IMPAIRMENT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	2239	96.9	96.9	96.9
Fatigue	1.	12	0.5	0.5	97.4
Hunger	2.	17	0.7	0.7	98.2
Thirst	3.	19	0.8	0.8	99.0
Elimination Urgency	5.	4	0.2	0.2	99.2
Others	7.	7	0.3	0.3	99.5
Muscle Spasm-Cramp	8.	8	0.3	0.3	99.8
N.A.	9.	4	0.2	0.2	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.24.1. RIDER BODY TATTOOS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	489	21.2	84.2	84.2
	1.	48	2.1	8.3	92.4
	2.	12	0.5	2.1	94.5
	3.	8	0.3	1.4	95.9
	4.	11	0.5	1.9	97.8
	5.	3	0.1	0.5	98.3
	6.	7	0.3	1.2	99.5
More Than Six	7.	3	0.1	0.5	100.0
Not Observed	8.	1729	74.8	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.25.1. RIDER ATTENTION TO DRIVING TASK

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Attention Diverted To Surrounding Traffic	1.	417	18.1	73.2	73.2
Attention Diverted To Non-Traffic Item	2.	111	4.8	19.5	92.6
Attention Diverted To Motorcycle Operation	3.	31	1.3	5.4	98.1
Inattentive Mode	4.	11	0.5	1.9	100.0
Not Observed	8.	475	20.6	MISSING	100.0
N.A.-Attention Focused On Driving Task	9.	1265	54.8	MISSING	100.0
	TOTAL	2310	100.0	100.0	

In these observations, it was clearly necessary that the observer have extensive motorcycle experience as well as traffic law enforcement experience.

10.26 Motorcycle Rider Stress on Day of Interview

Of approximately six hundred riders interviewed, 77 or about 13% reported some type of stress at the time of the interview. Table 10.26.1 shows the distribution of stresses related during the interview.

TABLE 10.26.1. RIDER STRESS ON DAY OF INTERVIEW

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None Observed	0.	2233	96.7	96.7	96.7
Conflict Family, Friends	1.	14	0.6	0.6	97.3
Work Conflict	2.	11	0.5	0.5	97.7
Death-Illness of Friend	3.	1	0.0	0.0	97.8
Financial Distress	4.	14	0.6	0.6	98.4
School Problem	5.	19	0.8	0.8	99.2
Legal-Police Problem	6.	5	0.2	0.2	99.4
Social Agency Problem	7.	1	0.0	0.0	99.5
Reward Stress	8.	12	0.5	0.5	100.0
	TOTAL	2310	100.0	100.0	

10.27 Motorcycle Rider Stated Front Brake Use

Riders interviewed in the exposure data were questioned regarding their average use of the front brake in stopping situations. Over five-eights reported using the front brake "always"; 82.5% reported front brake use "usually" or "always." The data are shown in Table 10.27.1.

TABLE 10.27.1. MOTORCYCLE RIDER STATED FRONT BRAKE USE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Never	0.	13	0.6	2.2	2.2
Sometimes	1.	92	4.0	15.3	17.5
Usually	2.	116	5.0	19.3	36.8
Always	3.	379	16.4	63.2	100.0
Not Observed	8.	1699	73.5	MISSING	100.0
N.A.-No Front Brake	9.	11	0.5	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.28 Motorcycle Passenger Involvement

Passenger involvement was determined from photos if the rider did not stop for an interview. In some instances, such as nighttime freeway exposures, poor visibility precluded accurate determination or usable photos. Passengers were present on 18.3% of the motorcycles passing exposure sites. This is shown in Table 10.28.1.

TABLE 10.28.1. NUMBER OF PASSENGERS

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
None	0.	1835	79.4	81.6	81.6
One	1.	409	17.7	18.2	99.8
Two	2.	3	0.1	0.1	100.0
Three	3.	1	0.0	0.0	100.0
Unknown	8.	62	2.7	MISSING	100.0
	TOTAL	2310	100.0	100.0	

10.29 Motorcycle Rider and Passenger Protective Equipment

The exposure data shows a general trend to less adequate coverage for passengers than riders. Helmet and eye protection use was lower among passengers and the weight of riding apparel was generally less. Rider apparel generally tends toward heavy-weight clothing while passenger apparel tends toward medium-weight. Given the almost daily riding habits of most of the riders interviewed, it would appear that riders dress more heavily in expectation of riding, while passengers are less dressed for a motorcycle ride. Perhaps this feature portrays the passengers motorcycle ride as an unexpected event.

High Visibility Upper Torso Coverage

Upper torso coverage offering high contrast conspicuity was evaluated for all riders passing exposure data collection sites. While the great majority of riders wore moderate-to-low conspicuity upper torso coverage, 5.1% wore highly conspicuous attire such as bright yellow, orange, day-glo and reflective upper torso garments. Table 10.29.1 shows this data.

Helmet Use

Riders passing exposure sites were helmeted slightly more than half the time, as shown in Table 10.29.2. The distribution of helmet coverage types is shown in Table 10.29.3. Full coverage predominates, followed closely by full facial coverage helmets. The majority of partial coverage helmets were worn by law enforcement and escort service motorcycle riders. Passenger helmet usage was lower than that for riders: 68.3% were unhelmeted.

TABLE 10.29.1. HIGH VISIBILITY UPPER TORSO GARMENT WORN?

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Yes	1.	112	4.8	5.1	5.1
No	2.	2072	89.7	94.9	100.0
Unknown	8.	126	5.5	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.29.2. RIDER HELMET USE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
No	0.	1037	44.9	47.8	47.8
Yes	1.	1131	49.0	52.2	100.0
Unknown	8.	142	6.1	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Helmet Color

The distribution of rider and passenger helmet color is shown in Table 10.29.4. White is the most frequent color, accounting for approximately three-eighths of the helmets.

Eye Protection

Some form of protection was worn over the eyes by 70.2% of the riders. However, the type of eye protection worn was about equally divided between glasses (and sunglasses) and more adequate coverage such as face shields and goggles. Passengers showed a much lower level of eye protection, (38.6%) usually in the form of glasses.

Among those riders required to wear glasses or contacts for vision correction (35.1% of those interviewed) nearly one-third were not wearing the required vision correction. Contact lenses were worn very little.

The data relating eye protection are shown in Table 10.29.5.

The data on rider eye correction worn are shown in Table 10.29.6.

TABLE 10.29.3. HELMET TYPE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
		Rider			
None Worn	0.	996	43.1	45.9	45.9
Partial	1.	137	5.9	6.3	52.3
Full	2.	517	22.4	23.8	76.1
Full Facial-105	3.	20	0.9	0.9	77.0
Full Facial-120	4.	457	19.8	21.1	98.1
Not Worn-On Motorcycle	6.	41	1.8	1.9	100.0
Unknown	8.	142	6.1	MISSING	100.0
	TOTAL	2310	100.0	100.0	
		Passenger			
None Worn	0.	277	12.0	57.6	57.6
Partial	1.	6	0.3	1.2	58.8
Full	2.	99	4.3	20.6	79.4
Full Facial-105	3.	2	0.1	0.0	79.4
Full Facial-120	4.	23	1.0	4.8	84.2
Not Worn-On Motorcycle	6.	3	0.1	0.1	84.3
Unknown	8.	71	3.1	16.0	100.0
N.A.	9.	1829	79.2	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.29.4. HELMET COLOR

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
		Rider			
White	1.	433	18.7	38.6	38.6
Yellow	2.	45	1.9	4.0	42.6
Orange	3.	95	4.1	8.5	51.1
Black	4.	172	7.4	15.3	66.4
Brown	5.	10	0.4	0.9	67.3
Blue	6.	90	3.9	8.0	75.3
Red	7.	112	4.8	10.0	85.3
Purple	8.	3	0.1	0.3	85.6
Green	9.	18	0.8	1.6	87.2
Silver-Gray	10.	87	3.8	7.8	94.9
Gold	11.	53	2.3	4.7	99.6
Others	97.	4	0.2	0.4	100.0
Unknown	98.	190	8.2	MISSING	100.0
N.A.	99.	998	43.2	MISSING	100.0
	TOTAL	2310	100.0	100.0	
		Passenger			
White	1.	43	1.9	34.4	34.4
Yellow	2.	6	0.3	4.8	39.2
Orange	3.	12	0.5	9.6	48.8
Black	4.	6	0.3	4.8	53.6
Brown	5.	3	0.1	2.4	56.0
Blue	6.	14	0.6	11.2	67.2
Red	7.	21	0.9	16.8	84.0
Green	9.	6	0.3	4.8	88.8
Silver-Gray	10.	13	0.6	10.4	99.2
Gold	11.	1	0.0	0.8	100.0
Unknown	98.	84	3.6	MISSING	100.0
N.A.	99.	2101	91.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.29.5. EYE PROTECTION

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
		Rider			
None	0.	564	24.4	29.8	29.8
Glasses-Sun Glasses	1.	665	28.8	35.2	65.0
Shields	2.	596	25.8	31.5	96.5
Goggles	3.	65	2.8	3.4	100.0
Unknown	8.	420	18.2	MISSING	MISSING
	TOTAL	2310	100.0	100.0	
		Passenger			
None	0.	222	9.6	63.2	63.2
Glasses-Sun Glasses	1.	69	3.0	19.7	82.9
Shields	2.	55	2.4	15.7	98.6
Goggles	3.	5	0.2	1.4	100.0
Unknown	8.	133	5.8	MISSING	100.0
N.A.	9.	1826	79.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.29.6. RIDER EYE CORRECTION WORN AT TIME OF INTERVIEW

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Required-Not Worn	0.	71	3.1	11.2	11.2
Glasses	1.	142	6.1	22.5	33.7
Contacts	2.	9	0.4	1.4	35.1
Not Observed	8.	1678	72.6	MISSING	MISSING
N.A.-Eye Corr. Not Required	9.	410	17.7	64.9	100.0
	TOTAL	2310	100.0	100.0	

Upper Torso Coverage

Upper torso coverage for the motorcycle riders passing exposure sites generally offered a moderate-to-high level or protection: Nearly half wore heavy cloth such as a heavy jacket or leathers. Only 1.6% wore nothing. Passengers showed a general trend to use less substantial coverage than riders; they wore leather jackets only half as often. Data for rider and passenger upper torso coverage are shown in Table 10.29.7.

TABLE 10.29.7. UPPER TORSO GARMENT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
		Rider			
None	0.	33	1.4	1.6	1.6
Light Cloth	1.	493	21.3	23.7	25.3
Medium Cloth	2.	577	25.0	27.8	53.1
Heavy Cloth	3.	681	29.5	32.8	85.9
Leather	4.	293	12.7	14.1	100.0
Unknown	8.	233	10.1	MISSING	100.0
	TOTAL	2310	100.0	100.0	
		Passenger			
None	0.	8	0.3	2.0	2.0
Light Cloth	1.	128	5.5	31.8	33.8
Medium Cloth	2.	123	5.3	30.6	64.4
Heavy Cloth	3.	115	5.0	28.6	93.0
Leather	4.	28	1.2	7.0	100.0
Unknown	8.	82	3.5	MISSING	100.0
N.A.	9.	1826	79.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Lower Torso Coverage

Rider and passenger lower torso coverage was predominantly medium and heavy cloth. This was usually a pair of levi's or equivalent denim. "None" as the amount of lower torso coverage was not limited to nudity (which was in fact observed at exposure sites); it also included bathing suits, shorts, etc. As with helmets and upper torso coverage, there is the general tendency of passengers to be somewhat less heavily dressed than riders.

The data relating lower torso coverage is shown in Table 10.29.8.

TABLE 10.29.8. LOWER TORSO GARMENT

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
		Rider			
None	0.	20	0.9	1.0	1.0
Light Cloth	1.	62	2.7	3.1	4.1
Medium Cloth	2.	1014	43.9	50.2	54.3
Heavy Cloth	3.	914	39.6	45.2	99.5
Leather	4.	10	0.4	0.5	100.0
Unknown	8.	290	12.6	MISSING	100.0
	TOTAL	2310	100.0	100.0	
		Passenger			
None	0.	11	0.5	2.8	2.8
Light Cloth	1.	23	1.0	5.8	8.5
Medium Cloth	2.	199	8.6	49.9	58.4
Heavy Cloth	3.	166	7.2	41.6	100.0
Unknown	8.	86	3.7	MISSING	100.0
N.A.	9.	1825	79.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Hand Protection

Some type of glove was worn by nearly half the riders, but by only one passenger in six. These data are shown in Table 10.29.9 for riders and passengers.

Foot Coverage

Foot coverage among motorcycle riders was generally medium-weight to heavy-weight shoes. Nearly half wore heavy shoes or boots, while only 0.5% wore nothing on their feet. Passenger foot coverage was most often medium-weight shoes. The data for riders and passengers are shown in Table 10.29.10.

Safety Helmet Use Characteristics

Helmets were worn by 52.2% of the riders passing exposure sites, as shown in 10.29.2. The use or non-use of a helmet was crosstabulated with the principal factors of temperature, weather, rider education and occupation, sex, trip plan, trip length, and motorcycling experience. Helmet use tends to increase with age, education and trip length; it is higher among the white collar and service occupations. Helmet use tends to decrease as weather gets warmer. Helmet use appears to be unrelated to sex or to number of days per week riding.

TABLE 10.29.9. GLOVES

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
Rider					
None	0.	960	41.6	50.2	50.2
Light	1.	121	5.2	6.3	56.6
Medium	2.	474	20.5	24.8	81.4
Heavy	3.	356	15.4	18.6	100.0
Not Observed	8.	399	17.3	MISSING	100.0
	TOTAL	2310	100.0	100.0	
Passenger					
None	0.	265	11.5	82.8	82.8
Light	1.	15	0.6	4.7	87.5
Medium	2.	33	1.4	10.3	97.8
Heavy	3.	7	0.3	2.2	100.0
Not Observed	8.	165	7.1	MISSING	100.0
N.A.	9.	1825	79.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

Safety Helmet Use and Weather Conditions

Helmet use is equally divided when weather conditions are clear, but increases considerably when the weather turns cloudy. The data are shown in Table 10.29.11.

Safety Helmet Use and Temperature

Helmet use varies inversely with temperature: As temperatures drop helmet use goes up, and when temperatures rise, especially over 90°F, helmet use declines. As such, it appears that although helmets are designed as crash protection, many of the occasional wearers of helmets use them simply as a means of weather protection. During the first summer of data collection it appeared that helmet use dropped noticeably when the first heat wave pushed temperatures over 85°F. Indeed, the data seems to bear out this informal observation; helmet use is stable at about 50% in the 60°-80°F range and drops markedly above that range. These data on helmet use by temperature are shown in Table 10.29.12.

Safety Helmet Use by Age

Safety helmet use and age were determined for 616 riders in the exposure data. Of these, 46.1% were helmeted. The data for rider age and helmet use were cross-tabulated in Table 10.29.13. Helmet use increased from less than 20% in the under-17 age group to approximately 40% in riders 17-26, 50.8% for those 27-39 years old, and approximately 60% among those 40 and over.

TABLE 10.29.10. FOOT COVERAGE

Category Label	Code	Absolute Frequency	Relative Frequency (%)	Adjusted Frequency (%)	Cumulative Frequency (%)
		Rider			
None	0.	9	0.4	0.5	0.5
Sandals, Tennis Shoes	1.	306	13.2	16.0	16.5
Medium Street Shoes	2.	703	30.4	36.7	53.2
Heavy Shoe, Boot	3.	895	89.7	46.8	100.0
Not Observed	8.	397	17.2	MISSING	100.0
	TOTAL	2310	100.0	100.0	
		Passenger			
None	0.	10	0.4	2.7	2.7
Sandals, Tennis Shoes	1.	101	4.4	27.2	29.8
Medium Street Shoes	2.	153	6.6	41.1	71.0
Heavy Shoe, Boot	3.	108	4.7	29.0	100.0
Not Observed	8.	113	4.9	MISSING	100.0
N.A.	9.	1825	79.0	MISSING	100.0
	TOTAL	2310	100.0	100.0	

TABLE 10.29.11. SAFETY HELMET USE AND WEATHER CONDITIONS

Weather	Count Row Pct Col Pct Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
Clear		902 50.0 88.4 42.3	902 50.0 81.1 42.3	1804 84.5
Rain		1 100.0 0.1 0.0	0 0.0 0.0 0.0	1 0.0
Drizzle		0 0.0 0.0 0.0	2 100.0 0.2 0.1	2 0.1
Cloudy or Partly Cloudy		119 36.5 11.6 5.6	207 63.5 18.6 9.7	326 15.3
	Column Total	1022 47.9	1112 52.1	2134 100.0

TABLE 10.29.12. SAFETY HELMET USE BY AMBIENT TEMPERATURE

Temperature, °F	Count / Row Pct / Col Pct / Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
31-40		1 25.0 0.1 0.0	3 75.0 0.3 0.1	4 0.2
41-50		26 28.3 2.5 1.2	66 71.7 5.8 3.0	92 4.2
51-60		115 33.7 11.1 5.3	226 66.3 20.0 10.4	341 15.7
61-70		420 50.2 40.5 19.4	417 49.8 36.9 19.2	837 38.6
71-80		294 50.3 28.4 13.6	291 49.7 25.7 13.4	585 27.0
81-90		150 57.0 14.5 6.9	113 43.0 10.0 5.2	263 12.1
91-100		31 67.4 3.0 1.4	15 32.6 1.3 0.7	46 2.1
	Column Total	1037 47.8	1131 52.2	2168 100.0

TABLE 10.29.13. SAFETY HELMET USE BY RIDER AGE

Age	Count Row Pct Col Pct Tot Pct	Helmet Use No	Helmet Use Yes	Total
0-16 years		13 81.2 3.9 2.1	3 18.1 1.1 0.5	16 2.6
17-20		60 61.9 18.1 9.7	37 38.1 13.0 6.0	97 15.7
21-26		107 59.4 32.2 17.4	73 40.6 25.7 11.9	180 29.2
27-39		123 49.2 37.0 20.0	127 50.8 44.7 20.6	250 40.6
40-49		20 39.2 6.0 3.2	31 60.8 10.9 5.0	51 8.3
50-59		6 42.9 1.8 1.0	8 57.1 2.8 1.3	14 2.3
60-97		3 37.5 1.0 0.5	5 62.5 1.8 0.8	8 1.3
	Column Total	332 53.9	284 46.1	616 100.0

Safety Helmet Use by Sex

Helmets were worn by slightly more than half the male riders - 51.9%. Helmet use by females was slightly lower than that of males - 46.9%. The data are shown in Table 10.29.14.

TABLE 10.29.14. SAFETY HELMET USE BY SEX

Rider Sex	Count Row Pct Col Pct Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
Male		946 48.1 98.1 47.3	1022 51.9 98.6 51.1	1968 98.4
Female		17 53.1 1.8 0.8	15 46.9 1.4 0.7	32 1.6
Unknown		1 100.0 0.1 0.0	0 0.0 0.0 0.0	1 0.0
	Column Total	964 48.2	1037 51.8	2001 100.0

Safety Helmet Use by Education

Helmet use tends to increase with increasing levels of formal education. Overall safety helmet use in the exposure data was 51.8% Riders with a partial college education show approximately this level of use: 55.4% of them were helmeted when observed. Riders who had completed at least a bachelor's degree wore helmets 64.2% of the time, while those with only a partial high school education showed the lowest level of use, wearing a helmet in only 23.9% of the cases. This is shown in Table 10.29.15.

Safety Helmet Use by Occupation

Helmet use among various types of occupations shows a correspondence with education - occupations requiring a higher level of formal education tend to show a higher rate of helmet use: Riders from professional and administrative occupations (21.3% of those interviewed) showed 65% helmet use. Craftsmen, truckers, and laborers showed a 38.5% rate of helmet use. Service workers showed a very high level of helmet use (88%) in part because motorcycle police, who are required to wear a helmet, were a large portion of the service worker population. The data are shown in Table 10.29.16.

TABLE 10.29.15. SAFETY HELMET USE BY EDUCATION

Education	Count / Row Pct / Col Pct / Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
Graduate School Professional	Count	11	16	27
	Row Pct	40.7	59.3	4.4
	Col Pct	3.4	5.6	
	Tot Pct	1.8	2.6	
College Graduate	Count	29	54	83
	Row Pct	34.9	65.1	13.6
	Col Pct	8.9	18.9	
	Tot Pct	4.7	8.8	
Partial College	Count	103	129	232
	Row Pct	44.4	55.6	37.9
	Col Pct	31.5	45.3	
	Tot Pct	16.8	21.1	
High School Graduate	Count	105	55	160
	Row Pct	65.6	34.4	26.1
	Col Pct	32.1	19.3	
	Tot Pct	17.2	9.0	
Partial High School	Count	70	22	92
	Row Pct	76.1	23.9	15.0
	Col Pct	21.4	7.7	
	Tot Pct	11.4	3.6	
Junior High, Grammar School	Count	7	7	14
	Row Pct	50.0	50.0	2.3
	Col Pct	2.1	2.5	
	Tot Pct	1.1	1.1	
Less than 7 Years	Count	2	2	4
	Row Pct	50.0	50.0	0.7
	Col Pct	0.6	0.7	
	Tot Pct	0.3	0.3	
Column Total		327	285	612
		53.4	46.6	100.0

TABLE 10.29.16. SAFETY HELMET USE BY OCCUPATION

Occupation	Count Row Pct Col Pct Tot Pct	Helmet Use No	 Yes	Total
Professional		43	59	102
		42.2	57.8	15.2
		13.1	17.3	
		6.4	8.8	
Administrator		7	34	41
		17.1	82.9	6.1
		2.1	10.0	
		1.0	5.1	
Sales Worker		20	19	39
		51.3	48.7	5.8
		6.1	5.6	
		3.0	2.8	
Clerical		18	26	44
		40.9	59.1	6.6
		5.5	7.6	
		2.7	3.9	
Craftsmen		83	58	141
		58.9	41.1	21.0
		25.2	17.0	
		12.4	8.7	
Operatives		11	4	15
		73.3	26.7	2.2
		3.3	1.2	
		1.6	0.6	
Transport Operators		12	7	19
		63.2	36.8	2.8
		3.6	2.1	
		1.8	1.0	
Laborers		44	22	66
		66.7	33.3	9.9
		13.4	6.5	
		6.6	3.3	
Farm Laborers		1	0	1
		100.0	0.0	0.1
		0.3	0.0	
		0.1	0.0	
Service Workers		10	73	83
		12.0	88.0	12.4
		3.0	21.4	
		1.5	10.9	
Household Worker		1	0	1
		100.0	0.0	0.1
		0.3	0.0	
		0.1	0.0	
Students		57	32	89
		64.0	36.0	13.3
		17.3	9.4	
		8.5	4.8	
Military		2	1	3
		66.7	33.3	0.4
		0.6	0.3	
		0.3	0.1	
Retired		3	4	7
		42.9	57.1	1.0
		0.9	1.2	
		0.4	0.6	
Unemployed		17	2	19
		89.5	10.5	2.8
		5.2	0.6	
		2.5	0.3	
	Column Total	329	341	670
		49.1	50.9	100.0

Safety Helmet Use by Riding Experience

Safety helmet use tends to increase among riders with more street riding experience. A number of factors may be involved in which unhelmeted riders are unequally eliminated from the riding population, or riders who continue riding beyond a year or so may simply become more cautious and increase their helmet use. Safety helmet use appears to be quite low among beginning riders (33.7%) and to level off near 50% for riders with three or more years riding experience. Those data for motorcycle riders for whom helmet use and riding experience were both known are shown in Table 10.29.17.

TABLE 10.29.17. RIDER STREET RIDING EXPERIENCE AND HELMET USE

Experience	Count Row Pct Col Pct Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
0-6 Months		55 66.3 17.0 9.1	28 33.7 10.0 4.6	83 13.8
7-12 Months		36 56.3 11.1 6.0	28 43.7 10.0 4.6	64 10.6
1-2 Years		48 56.5 14.8 8.0	37 43.5 13.3 6.1	85 14.1
2-3 Years		26 57.8 8.0 4.3	19 42.2 16.8 3.2	45 7.5
3-4 Years		22 45.8 6.8 3.6	26 54.2 9.3 4.3	48 8.0
4-5 Years		24 52.2 7.4 4.0	22 47.8 7.9 3.6	46 7.6
More than 5 Years		113 48.7 34.9 18.7	119 51.3 42.7 19.7	232 38.5
	Column Total	324 53.7	279 46.3	603 100.0

Helmet use does not show a similar consistent pattern over time when compared with experience on the observed motorcycle. Of 603 riders for whom experience and helmet use were known, helmet use appears to be highest (53%) with one to four years experience on the observed motorcycle, but to be lower (45%) before and after that. However, motorcycles over two years old made up only 18.9% of the observations here; consequently, raw numbers in the cells of Table 10.29.18 are small enough to limit the significance of these data.

TABLE 10.29.18. EXPERIENCE ON OBSERVED MOTORCYCLE AND HELMET USE

Experience	Count Row Pct Col Pct Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
0-6 Months		141 57.6 43.1 23.4	104 42.4 37.8 17.2	245 40.6
7-12 Months		81 57.9 24.8 13.4	59 42.1 21.4 9.8	140 23.2
1-2 Years		49 47.1 15.0 8.1	55 52.9 19.9 9.1	104 17.2
2-3 Years		17 47.2 5.2 2.8	19 52.8 6.9 3.2	36 6.0
3-4 Years		11 44.0 3.4 1.8	14 56.0 5.1 2.3	25 4.1
4-5 Years		12 54.5 3.7 2.0	10 45.5 3.6 1.7	22 3.6
More than 5 Years		16 51.6 4.9 2.7	15 48.4 5.4 2.5	31 5.1
	Column Total	327 54.2	276 45.8	603 100.0

Safety Helmet Use By Trip Plan

Safety helmet use varies with the trip plan and the patterns of use are complex. Basically, helmets tend to be used more when work is the origin or destination. Indeed, use is extremely high - 91.3% - when work is both origin and destination, as when a motorcycle is ridden in performance of a job - for example, messengers, police and funeral escort riders. On the other hand, helmet use is low when riding is for recreational purposes or for shopping and errands. For example, of 30 riders for whom "recreation" was both origin and destination, only 5 (16.7%) were helmeted. The low incidence of helmet use in recreational riding may well be related to weather and temperature. Recreational riding is more common in warm or hot weather when helmet use is lower.

"Home" as an origin or destination is indifferently related to helmet use. That is, home is the origin for roughly 40% of both the helmeted and unhelmeted riders, and the destination for about 28% of both groups.

Finally, a rider going to school is somewhat more likely to be helmeted, but will probably be bare-headed on the way home. This may be related to warmer temperatures during the trip home (presumably in the afternoon) which is also the same time of day that the probability of accident involvement is higher. The cross-tabulation of trip origin and destination for unhelmeted riders is shown in Table 10.29.19. The same data for helmeted riders are shown in Table 10.29.20.

Safety Helmet Use By Trip Length

Helmet use increases with increasing trip length, as shown in Table 10.29.21. Use was the lowest (28%) on trips of less than one mile, and increased steadily to 56.7% for trips longer than 50 miles.

Safety Helmet Use and Frequency of Riding

Safety helmet use and the number of days per week riding were identified for 647 riders. These data are cross-tabulated in Table 10.29.22. A large portion of the five- and six-day-a-week riders are helmeted: This can be attributed in part to motorcycle riders whose use of a motorcycle is work-related.

10.30 Sample Population Data From Motor Vehicle and Driver License Registry

Additional information was gathered from the California Department of Motor Vehicles to determine some characteristics of the driving population in the study area. For example, no exposure data were gathered to compare drivers of the other vehicle involved in the motorcycle accident with the larger population.

The ratio of motorcycle to automobile registrations in Los Angeles County is shown in Table 10.30.1 for the years of 1976 - 1979.

TABLE 10.29.19. TRIP PLAN FOR UNHELMETED RIDERS

Origin	Count Row Pct Col Pct Tot Pct	Destination: Home	Work	Shopping Errand	Recreation	Friends Relative	Bar Drinking Party	School	Unknown-Not Obs	N.A.	Row Total
Home		3	32	24	55	19	0	12	0	1	146
		2.1	21.9	16.4	37.7	13.0	0.0	8.2	0.0	0.7	14.1
		3.1	71.1	54.5	60.4	63.3	0.0	70.6	0.0	100.0	
		0.3	3.1	2.3	5.3	1.8	0.0	1.2	0.0	0.1	
Work		28	6	9	6	2	0	0	0	0	51
		54.9	11.8	17.6	11.8	3.9	0.0	0.0	0.0	0.0	4.9
		28.6	13.3	20.5	6.6	6.7	0.0	0.0	0.0	0.0	
		2.7	0.6	0.9	0.6	0.2	0.0	0.0	0.0	0.0	
Shopping Errand		19	4	4	1	3	0	0	0	0	31
		61.3	12.9	12.9	3.2	9.7	0.0	0.0	0.0	0.0	3.0
		19.4	8.9	9.1	1.1	10.0	0.0	0.0	0.0	0.0	
		1.8	0.4	0.4	0.1	0.3	0.0	0.0	0.0	0.0	
Recreation		18	0	0	25	0	0	0	2	0	45
		40.0	0.0	0.0	55.6	0.0	0.0	0.0	4.4	0.0	4.3
		18.4	0.0	0.0	27.5	0.0	0.0	0.0	0.3	0.0	
		1.7	0.0	0.0	2.4	0.0	0.0	0.0	0.2	0.0	
Friends Relative		16	1	7	3	4	0	2	0	0	33
		48.5	3.0	21.2	9.1	12.1	0.0	6.1	0.0	0.0	3.2
		16.3	2.2	15.9	3.3	13.3	0.0	11.8	0.0	0.0	
		1.5	0.1	0.7	0.3	0.4	0.0	0.2	0.0	0.0	
Bar Drinking Party		0	0	0	0	0	1	0	0	0	1
		0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.1
		0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	
		0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	
School		13	2	0	0	2	0	2	0	0	19
		68.4	10.5	0.0	0.0	10.5	0.0	10.5	0.0	0.0	1.8
		13.3	4.4	0.0	0.0	6.7	0.0	11.8	0.0	0.0	
		1.3	0.2	0.0	0.0	0.2	0.0	0.2	0.0	0.0	
Unknown-Not Obse		1	0	0	1	0	0	1	706	0	709
		0.1	0.0	0.0	0.1	0.0	0.0	0.1	99.6	0.0	68.4
		1.0	0.0	0.0	1.1	0.0	0.0	5.9	99.4	0.0	
		0.1	0.0	0.0	0.1	0.0	0.0	0.1	68.1	0.0	
N.A.		0	0	0	0	0	0	0	2	0	2
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.2
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	
Column Total		98	45	44	91	30	1	17	710	1	1037
		9.5	4.3	4.2	8.8	2.9	0.1	1.6	68.5	0.1	100.0

TABLE 10.29.20. TRIP PLAN FOR HELMETED RIDERS

Origin	Count / Row Pct / Col Pct / Tot Pct	Destination: Home	Work	Shopping Errand	Recreation	Friends Relative	School	Unknown-Not Obs	Row Total
Home	Count	2	37	15	41	19	16	0	130
	Row Pct	1.5	28.5	11.5	31.5	14.6	12.3	0.0	11.5
	Col Pct	2.3	33.6	57.7	71.9	65.5	88.9	0.0	
	Tot Pct	0.2	3.3	1.3	3.6	1.7	1.4	0.0	
Work	Count	51	63	7	8	2	2	0	133
	Row Pct	38.3	47.4	5.3	6.0	1.5	1.5	0.0	11.8
	Col Pct	59.3	57.3	26.9	14.0	6.9	11.1	0.0	
	Tot Pct	4.5	5.6	0.6	0.7	0.2	0.2	0.0	
Shopping Errand	Count	12	5	2	0	1	0	0	20
	Row Pct	60.0	25.0	10.0	0.0	5.0	0.0	0.0	1.8
	Col Pct	14.0	4.5	7.7	0.0	3.4	0.0	0.0	
	Tot Pct	1.1	0.4	0.2	0.0	0.1	0.0	0.0	
Recreation	Count	11	0	0	5	4	0	0	20
	Row Pct	55.0	0.0	0.0	25.0	20.0	0.0	0.0	1.8
	Col Pct	12.8	0.0	0.0	8.8	13.8	0.0	0.0	
	Tot Pct	1.0	0.0	0.0	0.4	0.4	0.0	0.0	
Friends Relative	Count	6	0	1	3	3	0	0	13
	Row Pct	46.2	0.0	7.7	23.1	23.1	0.0	0.0	1.1
	Col Pct	7.0	0.0	3.8	5.3	10.3	0.0	0.0	
	Tot Pct	0.5	0.0	0.1	0.3	0.3	0.0	0.0	
Bar Drinking Party	Count	1	0	0	0	0	0	0	1
	Row Pct	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	Col Pct	1.2	0.0	0.0	0.0	0.0	0.0	0.0	
	Tot Pct	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
School	Count	3	1	1	0	0	0	0	5
	Row Pct	60.0	20.0	20.0	0.0	0.0	0.0	0.0	0.4
	Col Pct	3.5	0.9	3.8	0.0	0.0	0.0	0.0	
	Tot Pct	0.3	0.1	0.1	0.0	0.0	0.0	0.0	
Unknown-Not Obse	Count	0	1	0	0	0	0	804	805
	Row Pct	0.0	0.1	0.0	0.0	0.0	0.0	99.9	71.2
	Col Pct	0.0	0.9	0.0	0.0	0.0	0.0	99.9	
	Tot Pct	0.0	0.1	0.0	0.0	0.0	0.0	71.1	
N.A.	Count	0	3	0	0	0	0	1	4
	Row Pct	0.0	75.0	0.0	0.0	0.0	0.0	25.0	0.4
	Col Pct	0.0	2.7	0.0	0.0	0.0	0.0	0.1	
	Tot Pct	0.0	0.3	0.0	0.0	0.0	0.0	0.1	
Column Total		86	110	26	57	29	18	805	1131
		7.6	9.7	2.3	5.0	2.6	1.6	71.2	100.0

TABLE 10.29.21. SAFETY HELMET USE AND TRIP LENGTH

Trip Length	Count / Row Pct / Col Pct / Tot Pct	Helmet Use		Total
		No	Yes	
0-1 Miles		36 72.0 11.3 6.1	14 28.0 5.1 2.4	50 8.5
1-5 Miles		99 59.3 31.1 16.8	68 40.7 25.0 11.5	167 28.3
5-50 Miles		157 50.2 49.4 26.6	156 49.8 57.4 26.4	313 53.1
More than 50 Miles		26 43.3 8.2 4.4	34 56.7 12.5 5.8	60 10.2
	Column Total	318 53.9	272 46.1	590 100.0

TABLE 10.29.22. SAFETY HELMET USE BY DAYS PER WEEK RIDING MOTORCYCLES

Days per Week	Count / Row Pct / Col Pct / Tot Pct	Helmet Use: No	Helmet Use: Yes	Total
0		2 100.0 0.6 0.3	0 0.0 0.0 0.0	2 0.3
1		16 59.3 4.9 2.5	11 40.7 3.4 1.7	27 4.2
2		17 43.6 5.2 2.6	22 56.4 6.8 3.4	39 6.0
3		29 64.4 8.9 4.5	16 35.6 5.0 2.5	45 7.0
4		20 71.4 6.2 3.1	8 28.6 2.5 1.2	28 4.3
5		35 26.5 10.8 5.4	97 73.5 30.1 15.0	132 20.4
6		18 32.1 5.5 2.8	38 67.9 11.8 5.9	56 8.7
7		188 59.1 57.8 29.1	130 40.9 40.4 20.1	318 49.1
	Column Total	325 50.2	322 49.8	647 100.0

TABLE 10.30.1. AUTOMOBILE/MOTORCYCLE REGISTRATIONS
LOS ANGELES COUNTY, 1976-1979

Year	Automobile Registrations / Motorcycle Registrations	Ratio
1976	3,922,277 / 198,325	19.8
1977	3,842,960 / 185,417	20.8
1978	3,922,701 / 178,744	21.9
1979	3,958,396 / 192,465	20.6

It is important to note that motorcycle registrations comprise one for every 20.8 automobile registrations. However, comparable data taken from Table 10.3.1, which defines median traffic flow on the motorcycle roadway in a one hour period, shows only one motorcycle for every 175 automobiles. This represents a spectacular proportion of the registered motorcycles that simply are not on the street! Seven out of eight registered motorcycles are in the the garage or stored!

This terrific gap between registrations and actual traffic exposure clearly indicates that studies of motorcycle accidents which utilize vehicle registrations as a measure of motorcycle use and exposure to accidents suffer a serious methodological gap. In previous time, the National Motor Vehicle Safety Advisory Council had recognized such a problem and recommended concurrent exposure and accident data collection. Comparisons of accident data and motorcycle rider license and vehicle registrations are completely without merit.

Driver Licenses

The proportion of licensed drivers with the Class 4 (motorcycle) endorsement was compared to the larger population of Class 3 (automobile) license holders, as shown in Table 10.30.2. It should be noted that roughly 99% of Class 4 endorsement holders also have a Class 3 License.

Age and sex data on Class 3 licensed car drivers in Los Angeles County were gathered for 1977, 1978 and 1979, and these data are shown in Tables 10.30.3 (appendix D.1), 10.30.4 (Appendix D.1) and 10.30.5 (appendix D.1) respectively. The median age for licensed car drivers in 1977 was 31.9 years; for 1978 it was 31.7, and 31.6 for 1979.

TABLE 10.30.2. AUTOMOBILE/MOTORCYCLE LICENSE QUALIFICATION LOS ANGELES COUNTY, 1977-1979

Year	Class 3 Licenses / Class 4 Endorsements	Ratio
1977	$\frac{4,375,646}{196,055}$	22.3
1978	$\frac{4,481,432}{204,598}$	21.9
1979	$\frac{4,535,235}{202,705}$	22.4

Age and sex data on Class 4 licensed motorcycle riders in Los Angeles County were gathered for 1977, 1978 and 1979, and these data are shown in Tables 10.30.6 (Appendix D.1), 10.30.7 (Appendix D.1) and 10.30.8 (Appendix D.1) respectively. The most significant part of these data is that the female motorcycle riders maintain motorcycle licenses far beyond their representation in actual traffic.

11.0 COMPARISONS OF ACCIDENT AND EXPOSURE DATA

Conspicuity Factors

11.1 Motorcycle Size-Engine Displacement

Since conspicuity of the motorcycle is affected by the size, shape and contrast of the forward profile of the motorcycle, it is clearly possible that big motorcycles are more conspicuous than small motorcycles. Since no silhouette was measured for the motorcycle and rider, the most convenient representation of size is the engine displacement. Table 11.1.1 shows the known motorcycle displacements in three groups for the exposure and accident data.

TABLE 11.1.1. COMPARISON OF MOTORCYCLE SIZE IN ACCIDENT AND EXPOSURE DATA

Engine Displacement, cc.	Exposure Data	OSID Data	TAR Data
0-250 Small, lightweight motorcycles, mopeds, minibikes, scooters.	15.1% (314)	22.6% (203)	25.1% (536)
251-500 Medium motorcycles	25.5% (530)	36.4% (327)	40.4% (865)
Greater than 501 Large and heavyweight motorcycles	59.4% (1233)	41.1% (369)	34.5% (738)
Total Known Size	(2077)	(899)	(2139)

In these data of Table 11.1.1 the group of mopeds, minibikes, scooters, small and lightweight motorcycles are significantly overrepresented in the accident data. However, the medium motorcycles are also significantly overrepresented in these accident data. The large and heavyweight motorcycles are significantly underrepresented in the accident data, supporting the proposition that big motorcycles could be more conspicuous and less accident-involved.

There are many factors which can contribute to reducing accident involvement for large motorcycles. In this analysis, only engine displacement is the measure used and it is sure that other effects contribute. For example, large motorcycles are more likely to be equipped with conspicuous fairings and windshields, and skilled riders with less risk-taking tendencies.

A final effect for consideration is the chronological fault of the exposure data. In the period of time between the collection of accident and exposure data, there was an apparent increase in the large and heavyweight motorcycles in the population-at-risk. There is the expectation that the

exposure data may portray an excess of large and heavyweight motorcycles. Therefore, the favorable underrepresentation of big motorcycles in the accident data may be due in part to the increase in the population past the time of the accident.

A collection of supplementary data regarding local sales of large and heavyweight motorcycles was made to estimate the effect of the sales of large motorcycles of 1978 and 1979 models. These estimates do not change the significant underrepresentation of the large and heavyweight motorcycles in these accident data.

11.2 Motorcycle Color

A view of the front of the motorcycle and rider is not likely to show much of the color of the motorcycle. That front view will expose the rider face and front of the helmet, the rider upper torso garment, the headlamp and front turn signals-running lights, handlebars, front forks, tire and wheel, and engine and head pipes. Perhaps a part of the forward surfaces of the gas tank and side panels will expose some of the basic color scheme. Those parts of the motorcycle so exposed are not likely to present any of the basic color of the motorcycle. Only when the motorcycle is equipped with a fairing will that color of the fairing predominate and have any prospect of contribution to conspicuity.

The principal colored surfaces which have any real potential for contribution to conspicuity are the fairing-shield and rider upper torso garment. Otherwise, the distant front view and conspicuity of any motorcycle is not likely to be affected by motorcycle color. It is far more likely that motorcycle color would associate best with rider personality, or simply model color availability.

Table 11.2.1 shows the motorcycle predominating color for the accident and exposure data. The predominating color of white is significantly underrepresented in these accident data and there is an important association of this color. There are not many white motorcycles, but there are a lot of motorcycles with white fairings and this is the critical contribution to the underrepresentation in accidents. The large white surface is a critical contribution to conspicuity to reduce accident involvement, and this conclusion is not adversely affected by the chronological fault of the exposure data.

The motorcycles with predominating colors of yellow and orange show a significant overrepresentation in these accident data. The last three years of motorcycle production has introduced a spectacular number of yellow dirt bikes but essentially no yellow or orange street bikes. This overrepresentation of yellow and orange motorcycles in accidents is not factual but due to the chronological fault of the exposure data. This is an unfortunate situation because bright orange and yellow are high visibility colors and have the potential of increasing motorcycle conspicuity.

Brown motorcycles are also rare in current time and not considered to be actually overrepresented in accidents. Black motorcycles are shown to be significantly underrepresented in these accident data, but black has been

TABLE 11.2.1. COMPARISON OF MOTORCYCLE COLOR IN ACCIDENT AND EXPOSURE DATA

Motorcycle Predominating Color	Exposure Data		900 OSIDs		3600 TARs	
	Count	Percent	Count	Percent	Count	Percent
White	142	7.2	44	4.9	93	2.8
Yellow	69	3.5	44	4.9	168	5.0
Orange	115	5.8	93	10.4	259	7.8
Black	489	24.8	109	12.1	563	16.9
Brown	96	4.9	70	7.8	223	6.7
Blue	335	17.0	163	18.2	577	17.3
Red	414	21.0	199	22.2	746	22.4
Purple	31	1.6	32	3.6	73	2.2
Green	115	5.8	66	7.3	295	8.8
Silver/Gray	97	4.9	23	2.6	99	3.0
Gold	48	2.4	42	4.7	145	4.3
Metal Flake	4	0.2	3	0.3	2	0.1
Others	14	0.7	10	1.1	93	2.8
Unknown	341	---	2	---	264	---
TOTAL	2310		900		3600	

the most popular color of the last three or four years models of street bikes. Consequently, the chronological fault of the exposure data precludes an accurate estimate of the effect of this color.

Blue and red show no significant differences in the exposure and accident populations, and there is the prospect of sample time differences contributing to this comparison.

11.3 Motorcycle Modifications Which Affect Conspicuity

As viewed by the driver of the other vehicle in the most frequent accident configurations, the motorcycle and rider is a relatively narrow silhouette. In this way, it would be expected that any increase of the apparent width—and height—the motorcycle silhouette would increase conspicuity and reduce accident involvement. The addition of a fairing and windshield would create an increase in the width and height of the frontal profile of the motorcycle, and tend to increase conspicuity. In addition, if the fairing were of light color contrasting with the adverse background, and if the fairing had an active contribution to conspicuity such as the "Leading Edge Lights" of the Vetter Windjammer fairing, the increase in conspicuity would be considerable.

The comparision of accident and exposure data for windshield and fairing use is shown in Table 11.3.1. Both windshield and fairing equipped motorcycles are shown to be significantly less accident-involved. The motorcycles equipped with fairings were usually equipped with windshields, and those motorcycles equipped with windshields only were usually equipped with a clear, full windshield mounted to the steering or handlebars.

TABLE 11.3.1. COMPARISION OF WINDSHIELD AND FAIRING FREQUENCIES IN ACCIDENT AND EXPOSURE DATA

A. Windshields — With or Without Fairings	Exposure Data	Accident Data	TOTAL
Windshield	414	108	522
No Windshield	1711	792	2503
TOTAL	2125	900	3025
	(χ^2 = 24.27)		

B. Fairings — With or Without Windshields	Exposure Data	Accident Data	TOTAL
Fairing	261	78	339
No Fairing	1864	822	2686
TOTAL	2125	900	3025
	(χ^2 = 7.95)		

A limit to the interpretation is necessary because of the chronological fault of the exposure data. The use of frame mounted fairings apparently increased during the time between accident data collection and exposure data collection, but the increase is not quantified.

11.4 Headlamp Use

The majority of motorcycle accidents present a front view of the motorcycle and rider to the driver of the other vehicle, i.e., the sum of the precrash lines-of-sight for 10, 11, 12, 1 and 2 o'clock directions from the motorcycle is 90.4%. This clearly establishes the conspicuity problem as relating to the frontal surfaces of the motorcycle. In this area, the highest contrast possible is provided by an operating headlamp. This prospect of significant contribution to conspicuity attracted much effort during the data collection. Much detailed accident investigation produced precise information on headlamp function and accurate reconstruction of the accident events. Also, the collection of exposure data focused on accurate headlamp information.

During the period of time between accident data collection and exposure data collection, a large number of newer model motorcycles incorporated the "automatic-on" headlamp function to provide increased conspicuity for those motorcycles. In part, this change in the population-at-risk represents another chronological fault of the exposure data. However, most of the "automatic-on" headlamp motorcycles can be extracted from the data by identifying the 1978 and 1979 models within the total exposure data. Also, a reinforcement of exposure data was provided independent of this research activity to establish a benchmark for helmet and headlamp use.

The data relating the effect of headlamp use on conspicuity are shown in Table 11.4.1. Within this table are shown the accident and exposure data for headlamp use, for daylight, dusk-dawn, and nighttime. The exposure data are shown for all known cases of headlamp use (a) then the exposure data are modified by extracting the part of the data related to 1978 and 1979 models (b). The accident data are shown for all known cases of headlamp use (a) then modified by presenting those cases where the precrash lines-of-sight were 11, 12, and 1 o'clock direction from the motorcycle.

TABLE 11.4.1. EFFECT OF HEADLAMP USE ON CONSPICUITY COMPARISION OF ACCIDENT AND EXPOSURE DATA

		Known Headlamp Use		
Daylight		On	Off	TOTAL
a. Exposure Data Total		1006	463	1469
b. Exposure Data without 1978-1979 models		657	416	1073
c. Exposure Data for 1978-1979 Models		349	47	396
d. Accident Data Total		166	359	525
e. Accident Data for 11-12-1 o'clock pre-crash lines-of-sight		137	265	402
Dusk-Dawn	a.	188	76	264
	b.	146	73	219
	c.	42	3	45
	d.	17	22	39
	e.	13	18	31
Night	a.	289	14	303
	b.	237	13	250
	c.	52	1	53
	d.	114	7	121
	e.	87	7	94

Note: On is equipped and on; Off is not on, not equipped, or not operating; Unknowns are not included.

The data of Table 11.4.1 show that those motorcycles using headlamps on in daylight are underrepresented in the accident data in a spectacular fashion. For example, consider the comparison of the modified exposure data and accident data for daylight conditions as follows:

	Headlamp On	Headlamp Off	TOTAL
Daylight Exposure Cases, No 78 and 79's	657	416	1073
Daylight Accident Data	166	359	525
TOTAL	823	775	1598

(χ^2 = 122.6)

In this comparison, the motorcycles with headlamps-on during daylight are underrepresented in the accident data almost by a factor of TWO! The modified daylight exposure cases (No 78 and 79's) appears to be a credible representation of the time of the accident data when compared with the separate benchmark data. The modified exposure data specifies 61.2% headlamp use and the benchmark data specifies 62.0% headlamp use (734 On, 449 Off, 1183 TOTAL known).

The data of Table 11.4.1 show that those motorcycles using headlamps on in dusk-dawn are also significantly underrepresented in the accident data.

The data of Table 11.4.1 show no important differences between night accidents and night exposure data. However, the implication is serious since being on the roadway at night without an operating headlamp is a high risk. Case by case review of the accidents of those motorcycles without operating headlamp showed accident involvement clearly related to some failure to see or be seen by other traffic.

The data shown in Table 11.4.1 provide a powerful argument for the use of the headlamp-on during all times of motorcycle operation. Recall from previous vehicle factors data that more than 90% of the accident-involved motorcycles with headlamp on had low beam selected. This argument in favor of the headlamp-on during all times of motorcycle operation is sure to be more powerful for high beam selected, especially in daylight where the contrast conspicuity need is great.

A final observation is the number of 1978 and 1979 models where the "automatic-on" headlamp was defective or intentionally disabled. A spot check of such models shows that at least 6% of these observed models have intentionally disabled "automatic-on" function and a selector switch has been installed.

11.5 High Visibility Upper Torso Garment

When the motorcycle is not equipped with a fairing, a large part of the frontal surface exposed is the upper torso of the motorcycle rider. Consequently the use of an upper torso garment which presents a large surface with a high visibility color can contribute greatly to conspicuity. A comparison of accident and exposure upper torso garment data is shown in Table 11.5.1. These data show a significant advantage of the motorcycle rider wearing a bright, high visibility yellow Yamaha jacket, orange Electro jacket, etc.

TABLE 11.5.1. HIGH VISIBILITY UPPER TORSO GARMENT USE IN ACCIDENT AND EXPOSURE DATA

High Visibility Upper Torso Garment Worn	Exposure Data	Accident Data	TOTAL
Yes	112	2	114
No	2072	886	2958
TOTAL	2184	888	3072
	(χ^2 = 41.1)		

11.6 Helmet Color

The view of the front of the motorcycle and rider will expose very little of a helmet surface, unless the helmet is full facial coverage. The largest area of color exposed by a full facial coverage helmet is no more than one-fifth that of an upper torso garment. Thus expectations that color of any contemporary helmet can affect conspicuity should be low.

Table 11.6.1 shows a comparison of helmet colors in the accident and exposure data. The frequency of white helmets in both accident and exposure data is high, and the reason is simply that white is the most commonly produced helmet color. The only color with significant difference between accident and exposure data is black. The explanation for the black helmet being overrepresented in the exposure data is the chronological fault of the exposure data. During the last three or four years, the popularity — hence production and use — of black helmets increased considerably.

This same chronological fault does not allow any meaningful evaluation of other helmet color contribution.

TABLE 11.6.1. HELMET COLOR CONTRIBUTION TO CONSPICUITY COMPARISON OF EXPOSURE AND ACCIDENT DATA

Helmet Predominating Color	Exposure Data		OSIDI Accident Data	
White	433	(38.6%)	125	(37.7%)
Yellow	45	(4.0%)	11	(3.3%)
Orange	95	(8.5%)	36	(10.8%)
Black	172	(15.3%)	20	(6.0%)
Brown	10	(0.9%)	13	(3.9%)
Blue	90	(8.0%)	42	(12.7%)
Red	112	(10.0%)	46	(13.9%)
Purple	3	(0.3%)	3	(0.9%)
Green	18	(1.6%)	5	(1.5%)
Silver/Gray	87	(7.8%)	20	(6.0%)
Gold	53	(4.7%)	8	(2.4%)
Others	4	(0.4%)	3	(0.9%)
TOTAL	1122	(100.0%)	332	(100.0%)
Unknown	190		29	

Motorcycle Rider Licensing and Training

11.7 Driver License Qualification

Table 11.7.1 provides a comparison of the license qualification for the motorcycle riders in the exposure and accident data. These data show that the accident-involved motorcycle rider is:

(i) Significantly without any license

(ii) Significantly without a motorcycle license.

Between the times of accident and exposure data collection, there was an increase in the number of motorcycle license (Class 4) holders in Los Angeles County. However, during this period of time, that increase was never greater than approximately 6% so the significance of the unlicensed riders is not diminished due to this change.

The success in the collection of exposure data depended greatly upon rider cooperation. At each exposure site, passing riders stopped voluntarily for interview and motorcycle examination. Several did not stop, and follow-up was attempted after vehicle license and registration identification. Many factors could affect this cooperation at the exposure site, or cooperative response to follow-up inquiry. The rider could be wary of government or law enforcement activity, improperly licensed, unauthorized to use the motorcycle, late for work, alcohol or drug involved, etc. None of these factors would logically relate that these noncooperating riders were better licensed than the cooperating riders. In this way, the exposure data are considered to be an acceptable representation of unlicensed riders.

TABLE 11.7.1. DRIVER LICENSE QUALIFICATION KNOWN RIDER LICENSE STATUS

License	Exposure Data		900 OSIDI Data		3600 TAR Data	
	Count	Percent	Count	Percent	Count	Percent
None (including revoked)	33	4.9	106	12.0	373	11.9
Class 1 Commercial	14	2.1	14	1.6		
Class 2 Chaffeur	9	1.3	1	0.1		
Class 3 Standard	97	14.3	256	28.7	1075	34.3
Class 4 Motorcycle	508	74.9	483	54.5	1589	50.7
Permit	17	2.5	27	3.0	96	3.1
TOTAL	678	100.0	887	100.0	3133	100.0

11.8 Motorcycle Rider Training Experience

During the period of accident data collection, there was very little specialized motorcycle training available to the motorcycle rider. Most of the accident-involved motorcycle riders were self-taught, or "learned" from friends and family, which offers very little transfer of factual information. This group was 92.0% of all the accident-involved riders.

During the period of exposure data collection, there was yet very little specialized motorcycle training available to the motorcycle rider. A comparison of the exposure and accident data of Table 11.8.1, shows that 84.3% of those riders were also self-taught, or learned from friends and family. However, while the greatest part of the population-at-risk is untrained, the trained motorcycle riders are significantly underrepresented in the accident data. The trained motorcycle rider is underrepresented in the accident data by an approximate factor of TWO.

TABLE 11.8.1. MOTORCYCLE RIDER KNOWN TRAINING EXPERIENCE

Known Training	Exposure Data		OSID Accident Data	
	Count	Percent	Count	Percent
Self-Taught	382	57.0	400	49.5
Friends-Family	183	27.3	343	42.5
School-Club M/C Course	68	10.1	41	5.1
Professional AMA, AFM, FIM	36	5.4	20	2.5
Others	1	0.1	4	0.5
TOTAL	670	100.0	808	100.0

11.9 Motorcycle Rider Street Bike Experience

The most common method of acquiring skills for riding a motorcycle in traffic is experience. Supposedly, the acquisition of experience will develop riding skills, collision avoidance skills, traffic strategy, etc. and thus prepare the motorcycle rider to deal with traffic hazards. The only obstacle within this system is the prospect of accident experience!

Just how much experience must be acquired to insulate the motorcycle rider?

Table 11.9.1 compares the motorcycle rider street bike experience for exposure and accident data. Both measures of experience are included: total experience and experience on the observed (or accident-involved) motorcycle. In this tabulation, the inexperienced riders (0-6 months) have significant overrepresentation in the accident data, with the most significant measure being the experience on the observed (or accident-involved) motorcycle. Beyond six months experience, the comparison is not illuminating until very high experience levels are reached. That group of riders with very high experience (>48 months) have a significant underrepresentation in the accident data, with the most significant measure being the experience on the observed (or accident-involved) motorcycle.

TABLE 11.9.1. MOTORCYCLE RIDER STREET BIKE EXPERIENCE

Known Experience	Exposure Data		Accident Data	
	Total Experience	On Observed Motorcycle	Total Experience	On Accident Motorcycle
0-6 months	84 (13.7%)	247 (40.4%)	156 (19.1%)	491 (57.4%)
7-12 months	64 (10.5%)	141 (23.1%)	83 (10.1%)	136 (15.9%)
13-24 months	86 (14.1%)	105 (17.2%)	107 (13.1%)	112 (13.1%)
25-36 months	46 (7.5%)	37 (6.1%)	93 (11.4%)	63 (3.0%)
37-48 months	49 (8.0%)	25 (4.1%)	64 (7.8%)	26 (3.0%)
>48 months	282 (46.2%)	56 (9.2%)	315 (38.5%)	27 (3.2%)
TOTAL	611	611	818	855

The conclusions are concise. Inexperience is excessively associated with accident involvement; and inexperience is best measured by the subject motorcycle. High levels of experience are underrepresented in accidents, but how is that considerable experience obtained without exposure to accidents? In these data shown, experience levels between seven months and four years does not clearly distinguish that experience as beneficial. Only when the experience is much greater than four years is there a significant benefit demonstrated.

It appears that specialized motorcycle rider training is the alternative which reduces risk; the acquisition of traffic experience only is simply accident exposure by comparison.

11.10 Dirt Bike Experience

Table 11.10.1 shows the dirt bike experience for the exposure and accident data. In these data, the motorcycle rider with some kind of dirt bike experience is significantly underrepresented in the accident data.

TABLE 11.10.1. DIRT BIKE EXPERIENCE

Known Dirt Bike Experience	Exposure Data	Accident Data	TOTAL
None	232	595	827
Yes	392	238	630
TOTAL	624	833	1457
	(χ^2 = 169.1)		

Motorcycle Rider Characteristics

11.11 Motorcycle Rider Age

Table 11.11.1 shows a comparison of exposure and accident data for age of the accident-involved motorcycle rider. Figure 11.11.2 presents these same data by graph for comparison.

The first comparison necessary is between the on-street Exposure Data and the 1977 and 1978 Los Angeles County Class 4 Registrations. These two sets of data differ significantly in many of the age groups, and portray much contrast between license registration and actual street traffic. The most substantial difference shows that riders of age beyond 35 participate in this traffic much less than in the licensed population. Also, it shows that the age groups 16-19, 25-29, and 30-34 participate in this traffic much more than in the licensed population.

The two sets of accident data shown are for the 900 on-scene, in-depth investigations and the 3600 traffic accident report cases. When these accident data are compared with the exposure data, it is clear that the motorcycle riders beyond age 50 contribute few accidents and are generally underrepresented in the accident data. Also, the motorcycle riders in the age groups between 30 and 50 are significantly underrepresented in these accident data, and the age groups between 16 and 24 are significantly overrepresented. This comparison identifies the age group between 16 and 24 as candidates for countermeasures of training and licensing. Recall from the Table 11.11.1 that there are many of the accident-involved riders below the

TABLE 11.11.1. MOTORCYCLE RIDER AGE DATA

Age Groups	Exposure Data		1977 and 1978 LA County Class 4 Average		900 OSID Accident Data		3600 TARs Accident Data	
	Count	Frequency	Count	Frequency	Count	Frequency	Count	Frequency
16-19	94	.1506	17703	.0884	107	.1201	742*	.2118
20-24	144	.2308	49377	.2465	299	.3356	1202	.3431
25-29	138	.2212	40083	.2001	210	.2357	712	.2033
30-34	119	.1907	29335	.1464	121	.1358	381	.1088
35-39	52	.0833	19074	.0452	67	.0752	196	.0560
40-44	31	.0497	13669	.0682	29	.0325	97	.0277
45-49	24	.0385	11384	.0568	22	.0247	73	.0208
50-54	8	.0128	8405	.0445	13	.0146	51	.0146
55-59	6	.0096	6057	.0302	13	.0146	30	.0086
60-64	4	.0064	3136	.0157	6	.0067	13	.0037
65-69	2	.0032	1208	.0060	2	.0022	3	.0009
70-74	2	.0032	345	.0017	1	.0011	0	0
75-79	0	0	42	.0002	1	.0011	3	.0009
80-84	0	0	10	-	0	0	0	0
85-89	0	0	3	-	0	0	0	0
90-99	0	0	0	0	0	0	0	0
Known TOTAL	624		200331		891		3503	
Unk.	1686				9		97	
TOTAL	2310							

*Includes 45 < 16 years

legal licensing age (45 of 742) and many without any license, permit or endorsement for motorcycle operation hence law enforcement countermeasures are appropriate.

11.12 Motorcycle Rider Sex, Marital Status, Children

Table 11.12.1 shows the sex of the motorcycle riders in the accident and exposure data. This comparison shows that the few female riders appear in few accidents, but are significantly overrepresented in these accidents. A review of the characteristics of those accidents involving female riders showed young riders, low experience, small motorcycles, and inferior collision avoidance action. Also, note that use of driver license registration does not reflect this excess accident involvement.

The exposure data is compared with accident data collection and it shows that the female motorcycle rider is less than 1.6% of the population-at-risk in this study area.

Table 11.12.2 shows the comparison of the number of children for the motorcycle riders in the accident and exposure data. No significant differences are shown between the accident-involved riders and the population-at-risk.

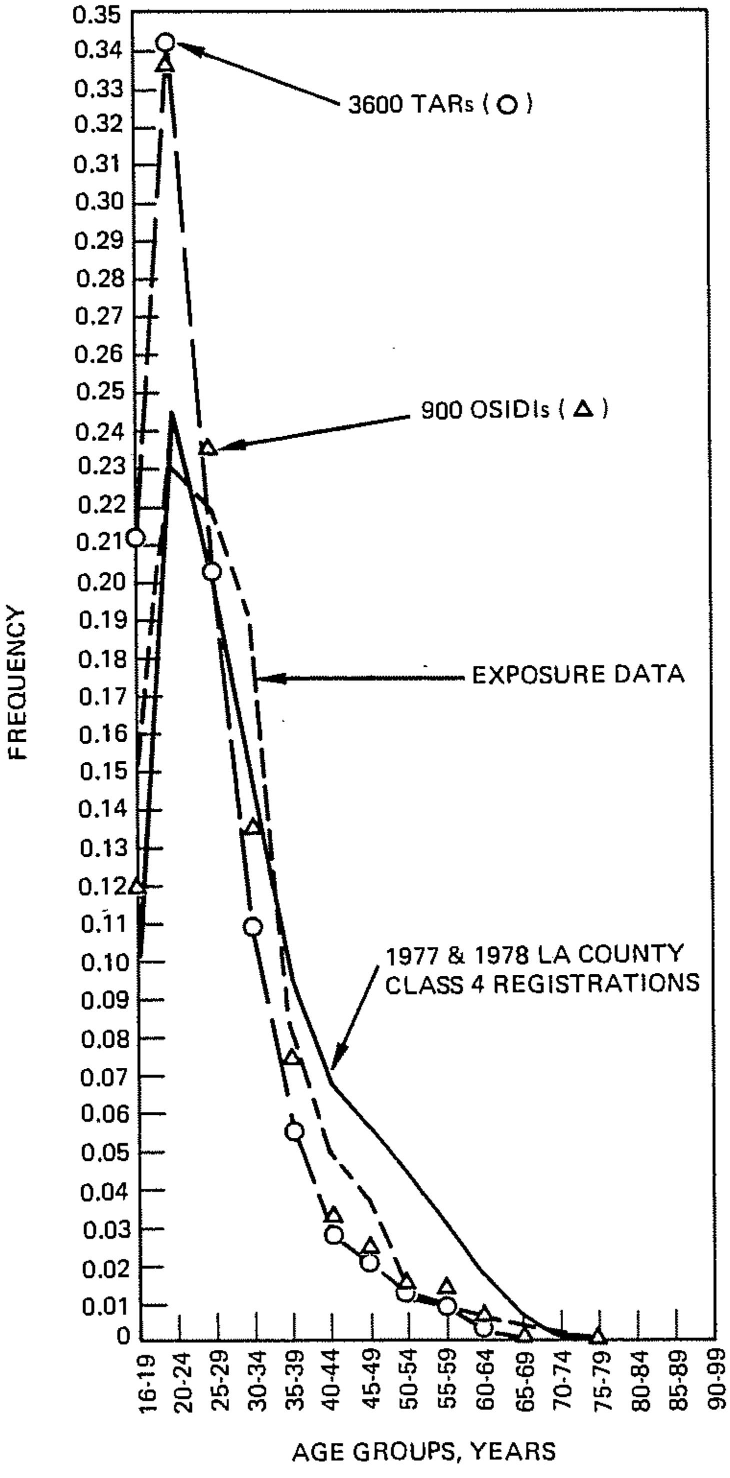


FIGURE 11.11.2. COMPARISON OF ACCIDENT AND EXPOSURE DATA, AGE OF THE MOTORCYCLE RIDER.

TABLE 11.12.1. MOTORCYCLE RIDER SEX

Known Rider Sex	2310 Exposure Cases	1977 and 1978 LA County Class 4 Average	900 OSIDIs	3600 TARs
Male	2045 (98.4%)	140839 (95.26%)	865 (96.1%)	3454 (97.1%)
Female	32 (1.4%)	9487 (4.74%)	34 (3.8%)	102 (2.8%)

TABLE 11.12.2. MOTORCYCLE RIDER NUMBER OF CHILDREN

Known Number of Children	Exposure Data		900 OSIDs Accident Data	
0	418	(67.4%)	572	(67.8%)
1	69	(11.1%)	109	(12.9%)
2	80	(12.9%)	84	(10.0%)
3	29	(4.7%)	37	(4.4%)
4	14	(2.3%)	22	(2.6%)
5	8	(1.3%)	10	(1.2%)
6	1	(0.2%)	5	(0.6%)
7	1	(0.2%)	5	(0.6%)

Table 11.12.3 shows the marital status for the motorcycle riders in the accident and exposure data. The married rider is underrepresented in the accident data, but the single rider is not overrepresented. The only distinction with significance is that the "cohabitating" motorcycle rider is overrepresented in the accident data. "Living-in-sin" shows one more hazard.

TABLE 11.12.3. RIDER MARITAL STATUS

Known Marital Status	Exposure Data		900 OSIDs Accident Data	
Single	373	(59.6%)	515	(59.6%)
Married	188	(30.0%)	230	(26.6%)
Separated, Divorced	50	(9.0%)	84	(9.8%)
Widowed	4	(0.6%)	1	(0.1%)
Cohabitating	11	(1.8%)	34	(3.9%)

11.13 Physical Characteristics

Comparison of accident and exposure data for motorcycle rider height and weight showed no significant differences. The distribution of recorded heights and weights was essentially the same for accident and exposure data.

11.14 Motorcycle Rider Education and Occupation

Table 11.14.1 shows the educational background of the motorcycle riders in the accident and exposure data. These data show a highly significant underrepresentation in the accident data for the motorcycle riders with a college degree. Also, these data show a highly significant overrepresentation in the accident data for the motorcycle rider with limited education, i.e. partial high school or less. Between these two extremes of education are at least 60% of the accident-involved motorcycle riders who are high school graduates, most with partial college training. Those riders with partial college training are significantly underrepresented in the accident data and the high school graduates are significantly overrepresented in the accident data.

TABLE 11.14.1. MOTORCYCLE RIDER EDUCATIONAL STATUS

Known Education	Exposure Data		900 OSID Accident Data	
Grad School-Professional	26	(4.2%)	23	(2.8%)
College Graduate	83	(13.4%)	43	(5.2%)
Partial College	237	(38.2%)	297	(35.9%)
High School Graduate	165	(26.6%)	230	(27.8%)
Partial High School	52	(14.8%)	203	(24.5%)
Jr. High, Grammar School	14	(2.3%)	17	(2.1%)
Less than 7 years	4	(0.6%)	14	(1.7%)

This comparison of educational status serves notice of limits for certain traditional countermeasures. High school Driver Education which includes specialized motorcycle safety instruction would not have reached one-fourth of these accident-involved riders. However, it would have reached a majority of the most significantly overrepresented groups. Also, safety education countermeasures with high intellectual content will not be correctly focused. A major target for safety education appears to be that group with high school education or less.

The observations of investigators during accident data collection were comparable to the previous comparison, but with additional specific observations. It was the general impression that the accident-involved motorcycle rider was not a typical motorcycle enthusiast. It seemed very rare that the accident-involved motorcycle rider had read contemporary motorcycle enthusiasts magazines, followed motorcycle racing activities, or understood such matters as "conspicuity", "countersteering", "brake balance", etc.

Table 11.14.2 shows the known occupations for the motorcycle riders in the accident and exposure data. The significant differences are as follows:

(i) Professionals, sales workers, and craftsmen are underrepresented in the accident data.

(ii) Laborers, students and unemployed (who were mostly laborers and craftsmen when employed) are overrepresented in the accident data.

TABLE 11.14.2. MOTORCYCLE RIDER OCCUPATION

Known Occupation	Exposure Data		Accident Data: 900 OSIDIs		Accident Data: 3600 TARs	
	Count	Percent	Count	Percent	Count	Percent
Professional	102	15.0	64	7.3	184	7.8
Administrative	42	6.2	24	2.7	116	4.9
Sales	39	5.8	13	1.5	62	2.6
Clerical	44	6.5	62	7.1	121	5.2
Craftsmen	148	21.8	155	17.7	312	13.3
Operatives	15	2.2	8	0.9	64	2.7
Transport	19	2.8	27	3.1	92	3.9
Laborers	67	9.8	138	15.8	438	18.7
Service Workers	83	12.3	85	9.7	283	12.1
Housewife	0	0.0	3	0.3	8	0.3
Student	89	13.1	185	21.2	486	20.7
Military	3	0.4	13	1.5	16	0.7
Retired	7	0.3	5	0.6	5	0.2
Unemployed	19	0.8	92	10.5	156	6.7
Total Known	677	100.0	874	100.0	2343	100.0

This comparison concisely describes students, laborers, and unemployed as a target group for safety education and countermeasures.

The chronological fault of the exposure data may reduce some significance assigned to the unemployed motorcycle rider participation in accidents. There was a reduction in the unemployed laborer population from approximately 11% during accident data collection to approximately 8% during exposure data collection. Also, in the circumstances of the interview it was less likely for the exposure interview to reveal the unemployed status. However, with these factors considered, the participation of the unemployed in the accident data is still considered a valid excess representation.

11.15 Motorcycle Rider Attention, Stress and Physiological Impairment

Table 11.15.1 provides a comparison of attention performance for the accident-involved motorcycle riders and those observed in the population-at-risk. The accident-involved riders show significantly less attention to traffic and driving tasks. While there are some few distractions to motorcycle operation, the major difference is that the accident population showed far greater basic attention problems with 19.1% operating in the inattentive mode.

Evaluation of associated factors does not completely explain this lack of attention to the driving tasks. The accident-involved motorcycle riders showed excess involvement with stress due to conflict with family and friends, and reward stress. However, these excess stress cases were few in number. Also, permanent physiological impairment was not involved or related although the temporary impairment from fatigue and hunger was overrepresented in the accident-involved motorcycle riders.

TABLE 11.15.1. MOTORCYCLE RIDER ATTENTION TO DRIVING TASK

Known Attention Direction	Exposure Data		Accident Data	
	Count	Percent	Count	Percent
Diverted to Surrounding Traffic	417	22.7	106	12.6
Diverted to Non-Traffic Item	111	6.0	43	5.1
Diverted to Motorcycle Operation	31	1.7	35	4.2
Inattentive Mode	11	0.6	161	19.1
Focused on Driving Task	1265	68.9	498	59.1
TOTAL	1835	100.0	843	100.0

11.16 Alcohol and Drug Involvement

Table 11.16 shows a comparison of exposure and accident data for alcohol and drug involvement. The comparison of known involvement for exposure cases and the on-scene in-depth cases shows an identical total involvement, 11.7%. However, the fatal accident cases show a total involvement of 43.1%, which is a highly significant overrepresentation.

TABLE 11.16.1. RIDER ALCOHOL AND DRUG INVOLVEMENT

Known Rider Involvement	Exposure Data		Accident Data			
			900 OSIDs		54 Fatals	
	Count	Percent	Count	Percent	Count	Percent
HBD-NUI	47	8.0	35	4.0	7	13.7
HBD-DUI	4	0.7	37	4.2	12	23.5
HBD Impairment Unknown	9	1.5	23	2.6	1	2.0
Drug Influence	5	0.8	3	0.3	1	2.0
Combination	4	0.7	5	0.6	1	2.0
None	516	88.2	773	88.2	29	56.9
TOTAL	585	100.0	876	100.0	51	100.0

Two factors may have caused the accident-involved motorcycle rider data to show too low an involvement in alcohol and drug use. Many of the interviews of the motorcycle riders were unavoidably conducted in the presence or proximity of authority figures. Interviews in the emergency room with the nurse, doctor, policeman and family nearby would surely limit factual expressions of drug or alcohol use. Also, the accident-involved motorcycle rider would be less free to divulge alcohol and drug use than would the non accident-involved motorcycle rider who voluntarily stops for exposure data interview.

However, in the fatal accident cases, ethanol and barbiturate use is detected by toxicological examination and recorded during autopsy. In this way, it is confirmed that the alcohol and drug use is overrepresented in those most severe accidents.

11.17 Tattoos, Hand Preference

Table 11.17.1 shows a comparison of exposure and accident data for motorcycle rider tattoos. The tattooed riders are overrepresented in the 900 OSID data, and more significantly overrepresented in the fatal accident data. The exposure data would tend to increase the significance of these findings by showing a slightly lower incidence of tattoos in the population-at-risk at the time of the accident data collection.

TABLE 11.17.1. MOTORCYCLE RIDER TATTOOS

Known Tattoos	Exposure Data		Accident Data			
			900 OSIDs		54 Fatals	
	Count	Percent	Count	Percent	Count	Percent
0	489	84.2	631	80.0	38	71.7
1	48	8.3	75	9.5	6	11.3
2	12	2.1	43	5.4	3	5.7
3	8	1.4	15	1.9	2	3.8
4	11	1.9	8	1.0	1	1.9
5	3	0.5	2	0.3	1	1.9
6	7	1.2	4	0.5	1	1.9
7 or more	3	0.5	11	1.4	1	1.9
TOTAL Known	581	100.0	789	100.0	53	100.0

The hand preference data for the motorcycle riders are shown in Table 11.17.2. In these data the left-handed motorcycle rider is not overrepresented in the accident data. The data collection techniques differed between accident and exposure data to the extent that right and ambidextrous should be combined for comparison. In this way, accident and exposure data are essentially equivalent (89.2% vs. 88.9%) and there is no significant distinction to rider hand preference.

TABLE 11.17.2. MOTORCYCLE RIDER HAND PREFERENCE

Known Hand Preference	Exposure Data		Accident Data	
	Count	Percent	Count	Percent
Right	502	80.7	712	85.4
Left	69	11.1	90	10.8
Ambidextrous	51	8.2	32	3.8
TOTAL Known	622	100.0	834	100.0

11.18 Motorcycle Rider Driving Record

Table 11.18.1 shows the driving record for the motorcycle rider by listing the accident and moving violation experience for the last two years. The motorcycle riders with moving violations are overrepresented in the accident data. This overrepresentation is with very high signficance at all citation levels. The motorcycle riders with previous accidents are also significantly overrepresented in the accident data. In these data the citation experience is more significant than the accident experience.

TABLE 11.18.1. MOTORCYCLE RIDER VIOLATIONS AND ACCIDENTS LAST TWO YEARS

Known Experience	Exposure Data		Accident Data	
	Count	Percent	Count	Percent
Violations 0	306	52.2	325	38.6
1	116	19.8	217	25.8
2	70	11.9	129	15.3
3	39	6.7	68	8.1
4	18	3.1	38	4.5
5	12	2.0	23	2.7
6	8	1.4	14	1.7
More than 6	17	2.9	27	3.2
TOTAL	587	100.0	841	100.0
Accidents 0	440	76.0	587	69.2
1	106	18.3	200	23.6
2	23	4.0	41	4.8
3	7	1.2	18	2.1
4	1	0.2	2	0.2
5	0	0.0	0	0.0
6	1	0.2	0	0.0
More than 6	1	0.2	0	0.0
TOTAL	579	100.0	848	100.0

These comparisons of accident and exposure data reinforce positions regarding the combined action of law enforcement and training. The option of "traffic school" instead of fines for moving violations provides a viable contact with potential accident cases, where the education or training has the prospect of preventing future accident involvement.

11.19 Route Familiarity, Trip Plan, and Motorcycle Use

The characteristic patterns of motorcycle use portrayed by these data are complex, and in many ways contradicting. No neat, simple description of motorcycle use relates precisely to accident involvement.

Table 11.19.1 shows the days per week that the motorcycle rider uses a motorcycle. The outstanding comparison of accident and exposure data is that for "zero" days, where the accident-involved, or observed rider, uses a motorcycle much less than one-half day per week. This comparison shows that the occasional rider, although a small part of both accident and exposure populations, is spectacularly overrepresented in the accident data. Such excess involvement by the occasional operator is typical in many areas of accidents, i.e. aviation, maritime, industrial, etc.

TABLE 11.19.1. DAYS PER WEEK MOTORCYCLE RIDDEN

Known Days	Exposure Data		Accident Data	
	Count	Percent	Count	Percent
0	3	0.5	61	7.4
1	27	4.1	33	4.0
2	39	6.0	45	5.4
3	45	6.9	54	6.5
4	29	4.4	43	5.2
5	134	20.5	86	10.4
6	58	8.9	39	4.7
7	320	48.9	468	56.5
TOTAL	655	100.0	829	100.0

Other significant differences within Table 11.19.1 provide contradiction: The 5-day rider is underrepresented in the accident data but the 7-day rider is overrepresented. An appropriate explanation—which is supported by other data—is that the work oriented travel may be less accident-involved than shopping-errands, friends-family or entertainment-recreation oriented travel.

Table 11.19.2 shows the comparison of accident and exposure data for the motorcycle rider familiarity with the roadway. When frequent* use of the roadway is compared with infrequent use, the infrequent use is overrepresented in the accident data. The only significant factor in these accident data is the motorcycle rider who had never before been on the road at the accident scene. This result relates a true need for caution by the motorcycle rider when traveling on unfamiliar roadways.

Table 11.19.3 shows a comparison of the time riding before the accident or observation at the exposure site. These data show clearly that the accident occurs relatively close to the origin of the trip and only a short time after departure. The short trip, and the short time riding before the accident, is a special feature of the accident-involved motorcycle rider. Note that 95% of the accidents occurred within the first hour; 50% occurred within the first six minutes!

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*Frequent: Daily to 1-2 times quarterly, infrequent: never before and less than annual.

TABLE 11.19.2. MOTORCYCLE RIDER FAMILIARITY WITH ROADWAY

Known Use	Exposure Data		Accident Data	
	Count	Percent	Count	Percent
Never Before	48	7.4	85	10.3
Daily	312	48.1	386	46.8
1-4 Times Weekly	134	20.7	205	24.9
1-3 Times Monthly	83	12.8	73	8.9
1-2 Times Quarterly	24	3.7	20	2.4
1-3 Times Annually	38	5.9	33	4.0
Less than Annually	9	1.4	22	2.7
TOTAL	648	100.0	824	100.0

TABLE 11.19.3. TIME RIDING BEFORE ACCIDENT/OBSERVATION

Known Time Riding, Hrs.	Exposure Data Cumulative Frequency, %	Accident Data Cumulative Frequency, %
0.0	3.9	21.2
0.1	31.6	49.4
0.2	49.1	67.8
0.3	62.6	81.4
0.4	65.9	82.8
0.5	77.2	88.7
0.7	80.0	90.9
1.0	87.5	94.5
2.0	93.6	97.6
	(584 cases)	(822 cases)

Table 11.19.4 shows a comparison of trip origin and destination for the accident and exposure data. In these data, the origins of bar-drinking party, shopping-errand, and friends-relatives, are significantly overrepresented in the accident data. Recall that the accident is more likely to occur close to the origin. The destinations of shopping-errand, friends-family, and home are significantly overrepresented in the accident data.

Note that work oriented travel is underrepresented in the accident data for both origin and destination.

11.20 Motorcycle Rider Protective Equipment

The protective equipment worn by the motorcycle rider was recorded and compared for the accident and exposure data. The most important factor of protection was the safety helmet, and Table 11.20.1 provides a comparison of accident and exposure data for the types of safety helmets worn. The most outstanding factor is the highly significant difference in helmet use; 52.2%

TABLE 11.19.4. RIDER TRIP PLAN

Known Origin	Exposure Data Adjusted Frequency, %	Accident Data Adjusted Frequency, %
Home	42.8	38.3
Work	28.2	19.8
Shopping	7.8	10.8
Recreation	10.2	9.4
Friends/Relatives	7.0	14.6
Bar/Drinking Party	0.3	2.2
School	3.7	5.0
	(656 cases)	(823 cases)
Known Destination		
Home	28.0	32.9
Work	24.1	18.4
Shopping	10.6	17.1
Recreation	22.7	14.7
Friends/Relatives	9.1	13.8
Bar/Drinking Party	0.2	0.1
School	5.3	3.0
	(660 cases)	(832 cases)

TABLE 11.20.1. MOTORCYCLE RIDER SAFETY HELMET USE

Known Helmet Coverage Type	Exposure Data		Accident Data	
	Count	Percent	Count	Percent
Partial	137	6.3	32	3.6
Full	517	23.8	197	22.4
Full Facial	477	22.0	113	12.9
None Worn	1037	47.8	536	61.0
TOTAL	2168	100.0	878	100.0

of the population-at-risk were wearing some kind of safety helmet but only 39.0% of the accident population were using helmets. There are three possible explanations for this great difference:

(i) Voluntary helmet users are better informed, more mature and cautious, and less likely to be accident-involved.

(ii) Helmet wearers are involved in some accidents where accident severity is less and no significant injury occurs because of helmet use.

(iii) Failure to wear a safety helmet is an expression of risk-taking personality.

The chronological fault of the exposure data is not responsible for the difference between accident and exposure data for safety helmet use. Benchmark data were collected for helmet use in the study area before accident data collection, after accident data collection, and again at the conclusion of exposure data collection. The overall helmet use for the population-at-risk at these times was 50.1%, 52.8%, and 49.7%, which essentially validates this part of the exposure data.

An additional fact is present in these helmet use data: the accident-involved motorcycle rider not only shows less helmet use, but uses less helmet coverage. The full facial coverage helmet, which provides much greater protection is significantly underrepresented in the accident data.

The accident data showed a large part of the accident-involved motorcycle riders did not have any kind of eye protection, and had the prospect of limited or impaired vision for exposure of the unprotected eye to wind, dust, insects, etc. Table 11.20.2 compares the eye protection for the accident and exposure data and there is a spectacular underrepresentation of eye protection in the accident data. The accident-involved rider uses significantly less eye protection, and this lack of protection for vision may be one of the most critical elements related to accident causation.

TABLE 11.20.2. MOTORCYCLE RIDER EYE PROTECTION

	Exposure Data		Accident Data	
Known Eye Protection	Count	Percent	Count	Percent
None	564	29.8	368	46.6
Glasses/Sunglasses Only	665	35.2	209	26.5
Face Shield	596	31.5	185	23.4
Goggles	65	3.4	28	3.5
TOTAL	1890	100.0	790	100.0

Table 11.20.3 provides a detailed comparison of motorcycle rider apparel in use by the accident and exposure populations. The significant differences point out that the accident-involved riders were not well prepared for their accident; they had less substantial garments, gloves, and foot coverage. There is the subtle inference that prudent and mature motorcycle riders understand and appreciate Shipman's Law of Motorcycle Apparel*. They protect themselves with substantial garments, gloves, footwear, eye protection and helmets, then are less accident-involved in addition to being less injury-involved!

*Carl Shipman: "What you neglect to wear will uniquely determine how you fall, etc."

TABLE 11.20.3. MOTORCYCLE RIDER APPAREL

Known Use	Exposure Data Count	Exposure Data Percent	Accident Data Count	Accident Data Percent
Upper Torso Garment				
None	33	1.6	14	1.6
Light Cloth	493	23.7	248	28.9
Medium Cloth	577	27.8	226	26.3
Heavy Cloth	681	32.8	303	35.3
Leather	293	14.1*	67	7.8
TOTAL	2077	100.0	858	100.0
Lower Torso Garment				
None	20	1.0	2	0.2
Light Cloth	62	3.1	40	4.7
Medium Cloth	1014	50.2	664	77.3
Heavy Cloth	914	45.2*	149	17.3
Leather	10	0.5	4	0.5
TOTAL	1920	100.0	859	100.0
Gloves				
None	960	50.2	522	61.5
Light	121	6.3	34	4.0
Medium	474	24.8*	128	15.1
Heavy	356	18.6	165	19.4
TOTAL	1911	100.0	849	100.0
Foot Coverage				
None	9	0.5	3	0.4
Sandal/Athletic Shoe	306	16.0	147	17.4
Medium Street Shoe	703	36.7	340	40.2
Heavy Shoe/Boot	895	46.8*	356	42.1
TOTAL	1913	100.0	846	100.0

*Critical items for comparison

Vehicle Factors

11.21 Motorcycle Manufacturer

In the comparison of accident and exposure data, the extraordinary representation of any manufacturer would be difficult to explain on the basis of any factors of vehicle design. Because of the serious faults of chronology in these exposure data, the comparisons of exposure and accident data may create false impressions. Consequently, special limits must be given to the interpretation and use of these comparisons.

Table 11.21.1 shows the adjusted frequencies of participation of the major manufacturers in the accident and exposure data. Note that BMW, Harley-Davidson and Suzuki are significantly underrepresented in the accident data; Kawasaki is slightly underrepresented; and Honda, Yamaha and Triumph are significantly overrepresented in the accident data. BMW, Harley-Davidson and Triumph represent configurations of motorcycles that are characteristically distinguished from Honda, Kawasaki, Suzuki and Yamaha. There is a popular image presented that riders of BMW, Harley-Davidson and Triumph are all expert, experienced and skilled beyond the ordinary. Also, there is a popular image of the young and inexperienced rider operating the smaller, less expensive Honda, Kawasaki, Suzuki and Yamaha.

TABLE 11.21.1. COMPARISON OF MAJOR MANUFACTURERS IN ACCIDENT AND EXPOSURE DATA

Manufacturer	2310 Exposure Data	900 OSIDs Data	3600 TARs Data	54 OSID Fatals
BMW	2.8% (60)	1.6% (14)	1.3% (45)	3.7% (2)
Harley-Davidson	11.4% (241)	10.6% (95)	9.1% (321)	14.8% (8)
Honda	47.7% (1011)	55.7% (501)	53.0% (1872)	57.4% (31)
Kawasaki	10.5% (223)	8.1% (73)	9.3% (329)	3.7% (2)
Suzuki	7.3% (154)	4.4% (40)	4.4% (155)	3.7% (2)
Triumph	2.1% (44)	2.0% (18)	3.5% (122)	1.9% (1)
Yamaha	11.5% (243)	12.2% (110)	13.7% (482)	13.0% (7)
Total Known Cases	(2119)	(900)	(3531)	(54)

Because of the obvious contradictions in these comparisons of accident and exposure data, useful interpretations are limited and the data shown must be limited in application.

11.22 Motorcycle Size-Engine Displacement

In the comparison of accident and exposure data, the extraordinary representation of any size motorcycle would attract a variety of explanations based upon speed potential and typical rider experience. Because of the serious faults of chronology in these exposure data, the comparisons of exposure data may create false impressions and limits must be given to interpretations.

For example, in the period of time between the collection of accident and exposure data, most manufacturers introduced many new models of large and heavyweight motorcycles. In this way, there is the expectation that the exposure data may portray an excess of large and heavyweight motorcycles for comparison with a time appropriate for the accident data. Since vehicle registration data does not accurately represent motorcycle use data, there appears to be no way of satisfactory reconciliation of the chronological fault. Hence, interpretation must respect this limit.

Table 11.22.1 provides a comparison of accident and exposure data for the selected groups of motorcycle sizes. In this comparison, the lightweight (101-250cc.) motorcycles are significantly overrepresented in accidents. Also, the large (501-750cc.) and heavyweight (>750cc.) motorcycles are significantly underrepresented in these accidents. There are not sufficient fatal accident data to distinguish a significant participation in fatal accidents. However, recall from Section 8.8 that higher injury severity is associated with large motorcycles.

TABLE 11.22.1. COMPARISON OF MOTORCYCLE SIZE IN ACCIDENT AND EXPOSURE DATA

Engine Displacement, cc.	Exposure Data	900 OSIDs Data	3600 TARs Data	54 OSID Fatals
0 - 100	6.8%	9.2%	8.0%	3.7%
(Small)	(141)	(83)	(172)	(2)
101 - 250	8.3%	13.3%	17.0%	7.4%
(Lightweight)	(173)	(120)	(364)	(4)
251 - 500	25.5%	36.4%	40.4%	33.3%
(Medium)	(530)	(327)	(865)	(18)
501 - 750	35.9%	25.4%	25.0%	37.0%
(Large)	(746)	(228)	(534)	(20)
Over 750	23.4%	15.7%	9.5%	18.5%
(Heavyweight)	(487)	(141)	(204)	(10)
SUBTOTAL	(2077)	(899)	(2139)	(54)
Unknown or Omitted	233	1	1461	0
TOTAL	2310	900	3600	54

The popular image that big motorcycles are more accident-involved than small motorcycles is not supported in these data. All of the motorcycles less than 500cc. are overrepresented in accident involvement and the medium size (251-500cc.) are significantly over-involved in these data. The popular proposition which supports these data is that the riders of the large and heavyweight motorcycles are more mature, experienced, skilled, etc. In the same sense, riders of the overrepresented medium size motorcycles do not have that same maturity and experience.

11.23 Motorcycle Type

Any comparison of accident and exposure data to investigate the effect of motorcycle type has certain expectations of results. If a motorcycle configuration is not suited to the traffic environment, it would be expected to be more accident involved. Also, motorcycle configurations which closely identify risk-taking tendencies of the rider would be expected to be more frequently involved in accidents.

Table 11.23.1 provides a comparison of exposure data and accident data, and some expectations are confirmed but others are not confirmed. For example, dirt bikes are in an unfavorable environment on the street in traffic but they are in-fact present and are significantly overrepresented in these accidents. It is clear that enforcement is the appropriate countermeasure to limit this exposure of dirt bikes in traffic and resulting accident involvement.

TABLE 11.23.1. COMPARISON OF MOTORCYCLE TYPE IN ACCIDENT AND EXPOSURE DATA

Motorcycle Type	Exposure Data (2310 Cases)	Accident Data (900 OSIDs)	Accident Data (54 Fatal OSIDs)
Street OEM	76.4% (1764)	69.2% (623)	66.7% (36)
Dirt Bike	0.6% (14)	1.6% (14)	3.7% (2)
Dual Purpose ("Enduro")	5.1% (118)	11.1% (100)	11.1% (6)
Semi-chopper	3.8% (88)	7.1% (64)	7.4% (4)
Chopper	5.0% (115)	5.4% (49)	5.6% (3)
Cafe Racer	0.5% (11)	3.1% (28)	5.6% (3)
Other (Trike, Moped, Minibike)	4.7% (69)	2.4% (22)	0.0% (0)
Police	3.9% (91)	Not identified in these data	0.0% (0)
TOTAL	(2310)	(900)	(54)

Also, the dual purpose "enduro" motorcycle appears in these accident data significantly beyond its representation in the exposure data. Such a dual purpose motorcycle may not have the capability for braking and maneuvering for collision avoidance equivalent to a street motorcycle. Also, the dual purpose motorcycle may be operated by a rider who does not have the same maturity, experience or traffic strategy as the comparable rider of a street bike.

The semi-chopper motorcycle is typified by the following modifications: extended front forks, pull-back handlebars, custom seat, "Harley" rear wheel and tire, sissy bar, etc. These semi-choppers are significantly overrepresented in these accident data. The image of the semi-chopper is reduced maneuverability and braking for collision avoidance and risk-taking tendencies indicated by the modifications. This image does not apply so conveniently when the exposure and accident data for choppers are compared; the chopper bike is not significantly overrepresented in these data. Here, the popular image may relate a high level of risk-taking tendency but also a high level of skill and experience.

The cafe racer motorcycle is typified by the following modifications: clip-ons or low set (short) handlebars, rear-set foot controls, partial front fairing, custom pipes, racing tires, etc. All of this such racing type equipment is rarely accompanied by genuine racing skills, so the "cafe racer" motorcycle configuration should be closely identified with risk-taking tendencies. In this way, the "cafe racer" is essentially equivalent to the "sports car". However, note that the cafe racer is not necessarily a large displacement motorcycle in the same way that a sports car is not necessarily a large displacement automobile.

During the period of accident data collection, mopeds were rarely encountered and no special effort was made to identify them. Later, during the exposure data collection, there were more mopeds in the traffic population and then they were identified for data purposes. Thus, the comparison of accident and exposure data is feckless because of the chronological fault of the exposure data.

Police motorcycles were involved in accidents for which data were collected. However, the police motorcycles were not identified separately except for the exposure data. Recapitulation of the accident cases shows that the regular law enforcement motorcycles were underrepresented in the accident data by a factor of approximately three. On the other hand, (private service) funeral escort motorcycles were highly overrepresented in the accident data, and almost always at a high level of injury severity.

During the time between accident data collection and exposure data collection, many new model motorcycles were introduced and several models appeared less frequently in traffic. Many low riders and semi-chopper-like configurations became factory standard models, many more medium displacement models were introduced, genuine choppers appeared less frequently, and many more mopeds entered the traffic system. Hence, caution is due in the interpretation of these data but it appears that cafe racers, dual purpose bikes, dirt bikes, and semi-choppers are excessively involved in these accidents.

11.24 Motorcycle Modifications

Table 11.24.1 shows the motorcycle modifications from the exposure and accident data. Front suspension modifications, such as extended front forks, are essentially identical in accident and exposure data. Rear suspension modifications such as a "Harley" wheel and tire, modified rear shocks, struts, etc.

TABLE 11.24.1. COMPARISON OF MOTORCYCLE MODIFICATIONS FOR ACCIDENT AND EXPOSURE DATA

Motorcycle Modification	Exposure Data	Accident Data
Front Suspension	10.6%	10.2%
Rear Suspension	14.1%	19.1%
Crash Bars	18.1%	18.1%
Sissy Bar	29.8%	27.1%
Seat	23.1%	24.8%
Windshield (with or without fairing)	19.5%	12.0%
Fairing	12.3%	8.7%
Handlebars	24.8%	16.3%
Exhaust System	27.3%	30.1%

are significantly overrepresented in the accident data. These types of rear suspension modifications are generally related to the semi-chopper or cafe racer configuration and are therefore consistent associations with excess accident involvement.

Crash bars have identical representation in accident and exposure data. Consequently, it is implied that crash bar usage does not increase or decrease accident involvement. Also, recall from the accident injury data that crash bars have no net effect on injuries to protectable regions. If any net beneficial effect results from crash bar use, it will most likely be the reduction of engine side and case cover damage in minor accidents.

Sissy bar usage is essentially the same for accident and exposure data. Modified and custom seats also have approximately the same representation in accident and exposure data.

The accident-involved motorcycles utilized significantly <u>fewer</u> windshields and fairings. In addition to the contribution to motorcycle conspicuity, the motorcycle equipped with a windshield and fairing is likely to be a large displacement motorcycle, which is also underrepresented in the accident data. In addition, the popular image is that the motorcycle rider equipping the motorcycle with a fairing may have greater maturity, more experience, and is involved in longer trip plans. A final factor for consideration is that in the time between accident data collection and exposure data collection, there was an increase in the sale and use of frame-mounted fairings. The specific quantification of this change in fairing equipment for the population-at-risk is not known.

The underrepresentation of modified handlebars in the accident population is difficult to explain except by the chronological fault of the exposure data. During the last half of exposure data collection, many custom and low rider models were introduced by manufacturers and it is possible that some few of these OEM high-risers and pullbacks were mistaken as modifications during data collection.

The modified exhaust system was typical of many accident-involved motorcycles, and also typical of many motorcycles observed during exposure data collection. The modified exhaust is overrepresented in these data, but not with high significance. To be sure, the number of custom exhaust systems made for motorcycles during recent years has increased. Hence, the exposure data collected some long time after accident data are likely to show more exhaust modifications than the time of the accident occurrence.

Characteristics of the Other Vehicle Driver

11.25 Age and Sex

Exposure data were not collected for the other vehicle driver as was for the motorcycle rider. Basic driver license data were obtained for the times of accident data collection for Los Angeles County. Table 11.25.1 shows the comparison of age groups of the other vehicle drivers involved in the 900 on-scene, in-depth accident investigations, the 3600 traffic accident report cases, and the Class 3 (standard) license data for the Los Angeles County Drivers. The distribution of these data are shown in the Figure 11.25.2. The accident-involved drivers from the 3600 TARS in the age groups of 16-19 20-24 and 25-29 are overrepresented when compared with the age groups of all licensed drivers in Los Angeles County. The accident-involved drivers from the 900 OSIDs confirm the overrepresentation for the age groups 20-24 and 25-29, and also note excessive representation for drivers beyond 65 years. This noted excess representation beyond 65 years within the 900 OSID cases is most likely related to those cases being of slightly higher overall severity.

The overrepresentation of the age groups of 16-29 for the driver of the other vehicle is an expected result because of the excess representation of this age group in all motor vehicle accidents. However, this is an unexpected result since it would be anticipated that this younger age group would be more familiar with motorcycles. In this way, this age group would be expected to more readily notice motorcycles and less likely to fail to detect motorcycles in traffic.

The sex of the drivers of the other vehicles are as follows:

	Male	Female
900 OSIDs (617)	67.0%	33.0%
3600 TARs (2469)	65.5%	34.5%
1977 and 1978 Class 3 L.A. County (8,857,078)	53.2%	46.8%

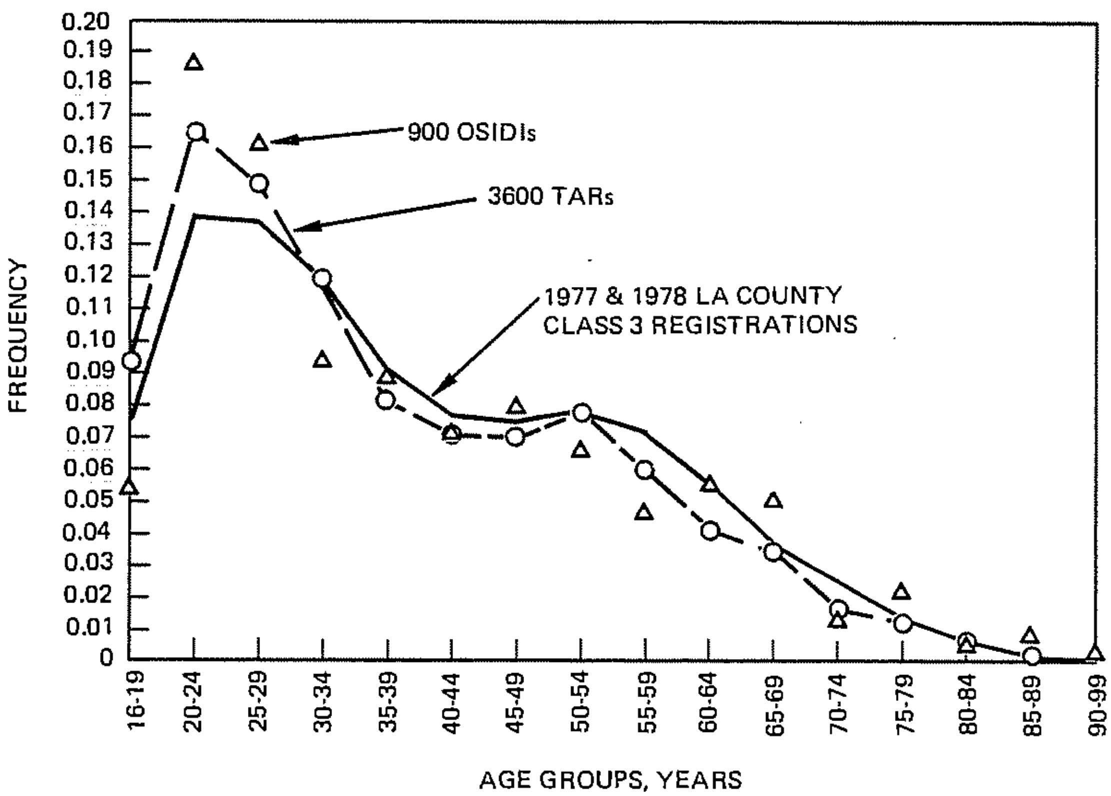
This comparison shows a significant overrepresentation of the male driver in both sets of accident data. There is no immediate explanation for this overrepresentation except to suspect the lack of suitable exposure data. This suspicion is confirmed in part by recent counts at accident sites. In these counts, the other vehicle drivers were 69.0% male. (702 male, 316 female, 24 unknown, 1072 total.)

TABLE 11.25.1. COMPARISON OF OTHER VEHICLE DRIVER AGE GROUPS AND LOS ANGELES COUNTY CLASS 3 REGISTRATIONS

Age Groups	900 OSIDs		3600 TARs		1977 and 1978 L.A. County Class 3 Average	
	Count	Frequency	Count	Frequency	Count	Frequency
16-19	33	.0535	232*	.0938	320981	.0725
20-24	115	.1864	408	.1652	615375	.1390
25-29	99	.1605	368	.1490	607573	.1372
30-34	58	.0940	293	.1187	524310	.1184
35-39	55	.0891	201	.0814	403204	.0910
40-44	44	.0713	175	.0709	338760	.0765
45-49	49	.0794	172	.0697	333167	.0752
50-54	40	.0648	93	.0782	344927	.0779
55-59	29	.0470	147	.0596	317052	.0716
60-64	34	.0551	101	.0409	248232	.0561
65-69	31	.0502	86	.0348	163944	.0370
70-74	8	.0130	39	.0158	109205	.0247
75-79	13	.0211	30	.0122	60389	.0136
80-84	3	.0049	15	.0061	25542	.0058
85-89	5	.0081	6	.0024	6455	.0015
90-99	1	.0016	3	.0012	673	.0002
TOTAL	617	1.0000	2469	1.0000	4428539	1.0000
Unknown	73		10			
N.A	210		1121			

*Includes 32 under 16 years of age.

FIGURE 11.25.2 COMPARISON OF ACCIDENT AND EXPOSURE DATA, AGE OF THE OTHER VEHICLE DRIVER



11.26 Other Vehicle Driver License Qualification and Driving Experience

Of the accident-involved drivers of the other vehicles, 6.1% had neither license nor permit, or were driving with license revoked. Exposure data were not collected for this aspect of driver qualification but comparisons of accident records show equivalent qualifications for all accident involvement. For example, review of samples of all traffic accidents in 1977 showed all accident involved drivers without current license were 6.91% (78 NLOP-NLIP, 1128 total).

The experience of the driver of the other vehicle has no outstanding differences from contemporary information.

11.27 Alcohol and Drug Involvement

The known total of alcohol and drug involvement of the other vehicle drivers was as follows:

OSIDs	6.4%
TARs	3.7%

The difference noted here is simply that alcohol and drug involvement noted on traffic accident reports is record of involvement for citation or arrest, and would tend to neglect lesser involvement.

No exposure data is available for comparison with the time of the accidents.

11.28 Other Vehicle Type

Table 11.28.1 provides a comparison of exposure and accident data for the type of other vehicle involved in the accident.

TABLE 11.28.1. VEHICLE SIZE AND TYPE

Type of Vehicle	Exposure Data for O/V Path	Vehicle Size OSIDs	Vehicle Size TARs	Vehicle Type OSIDs
Passenger Cars				88.7%
Full and Intermediate	44.1%	65.0%	62.0%	
Compact	16.5%	15.6%	12.6%	
Subcompact and Minis	25.8%	19.4%	22.5%	
Pickups and Vans	12.2%			7.7%
Trucks and Busses	1.4%			3.8%

During the time between collection of accident and exposure data, there was a distinct increase in vans and pickups in traffic. Because of this chronological fault of the exposure data, vans and pickups are not actually underrepresented in the accident data.

Also, there was an apparent increase in subcompact and minicars during this same time so the differences between exposure and accident data are not meaningful.

When the exposure data are compared on a very coarse level, passenger cars have equivalent representation and no particular type of vehicle is outstanding.

12.0 FINDINGS, RECOMMENDATIONS AND PROPOSED COUNTERMEASURES

12.1 Findings

Throughout the accident and exposure data there are special observations which relate to accident and injury causation and characteristics of the motorcycle accidents studied. These findings are summarized as follows:

*Approximately three-fourths of these motorcycle accidents involved collision with another vehicle, which was most usually a passenger automobile.

*Approximately one-fourth of these motorcycle accidents were single vehicle accidents involving the motorcycle colliding with the roadway or some fixed object in the environment.

*Vehicle failure accounted for less than 3% of these motorcycle accidents, and most of those were single vehicle accidents where control was lost due to a puncture flat.

*In the single vehicle accidents, motorcycle rider error was present as the accident precipitating factor in about two-thirds of the cases, with the typical error being a slide-out and fall due to overbraking or running wide on a curve due to excess speed or under-cornering.

*Roadway defects (pavement ridges, potholes, etc.) were the accident cause in 2% of the accidents; animal involvement was 1% of the accidents.

*In the multiple vehicle accidents, the driver of the other vehicle violated the motorcycle right-of-way and caused the accident in two-thirds of those accidents.

*The failure of motorists to detect and recognize motorcycles in traffic is the predominating cause of motorcycle accidents. The driver of the other vehicle involved in collision with the motorcycle did not see the motorcycle before the collision, or did not see the motorcycle until too late to avoid the collision.

*Deliberate hostile action by a motorist against a motorcycle rider is a rare accident cause.

*The most frequent accident configuration is the motorcycle proceeding straight then the automobile makes a left turn in front of the oncoming motorcycle.

*Intersections are the most likely place for the motorcycle accident, with the other vehicle violating the motorcycle right-of-way, and often violating traffic controls.

*Weather is not a factor in 98% of motorcycle accidents.

*Most motorcycle accidents involve a short trip associated with shopping, errands, friends, entertainment or recreation, and the accident is likely to happen in very short time close to the trip origin.

*The view of the motorcycle or the other vehicle involved in the accident is limited by glare or obstructed by other vehicles in almost half of the multiple vehicle accidents.

*Conspicuity of the motorcycle is a critical factor in the multiple vehicle accidents, and accident involvement is significantly reduced by the use of motorcycle headlamps-on in daylight and the wearing of high visibility yellow, orange or bright red jackets.

*Fuel system leaks and spills were present in 62% of the motorcycle accidents in the post-crash phase. This represents an undue hazard for fire.

*The median pre-crash speed was 29.8 mph, and the median crash speed was 21.5 mph, and the one-in-a-thousand crash speed is approximately 86 mph.

*The typical motorcycle pre-crash lines-of-sight to the traffic hazard portray no contribution of the limits of peripheral vision; more than three-fourths of all accident hazards are within 45° of either side of straight ahead.

*Conspicuity of the motorcycle is most critical for the frontal surfaces of the motorcycle and rider.

*Vehicle defects related to accident causation are rare and likely to be due to deficient or defective maintenance.

*Motorcycle riders between the ages of 16 and 24 are significantly overrepresented in accidents; motorcycle riders between the ages of 30 and 50 are significantly underrepresented.

*Although the majority of the accident-involved motorcycle riders are male (96%), the female motorcycle riders are significantly overrepresented in the accident data.

*Craftsmen, laborers and students comprise most of the accident-involved motorcycle riders but the professionals, sales workers and craftsmen are underrepresented and the laborers, students and unemployed are overrepresented in the accidents.

*Motorcycle riders with previous recent traffic citations and accidents are overrepresented in the accident data.

*The motorcycle riders involved in accidents are essentially without training; 92% were self-taught or learned from family or friends. Motorcycle rider training experience reduces accident involvement and is related to reduced injuries in the event of accidents.

*More than half of the accident-involved motorcycle riders had less than 5 months experience on the accident motorcycle, although the total street riding experience was almost 3 years. Motorcycle riders with dirt bike experience are significantly underrepresented in the accident data.

*Lack of attention to the driving task is a common factor for the motorcyclist in an accident.

*Almost half of the fatal accidents show alcohol involvement.

*Motorcycle riders in these accidents showed significant collision avoidance problems. Most riders would overbrake and skid the rear wheel, and underbrake the front wheel greatly reducing collision avoidance deceleration. The ability to countersteer and swerve was essentially absent.

*The typical motorcycle accident allows the motorcyclist just less than 2 seconds to complete all collision avoidance action.

*Passenger carrying motorcycles are not overrepresented in the accident data.

*The drivers of the other vehicle involved in collision with the motorcycle are not distinguished from other accident populations except that the ages of 20 to 29, and beyond 65 are overrepresented. Also, these drivers are generally unfamiliar with motorcycles.

*The large displacement motorcycles are underrepresented in accidents but they are associated with higher injury severity when involved in accidents.

*Any effect of motorcycle color on accident involvement is not determinable from these data, but is expected to be insignificant because the frontal surfaces are most often presented to the other vehicle involved in the collision.

*Motorcycles equipped with fairings and windshields are underrepresented in accidents, most likely because of the contribution to conspicuity and the association with more experienced and trained riders.

*Motorcycle riders in these accidents were significantly without motorcycle license, without any license, or with license revoked.

*Motorcycle modifications such as those associated with the Semi-Chopper or Cafe Racer are definitely overrepresented in accidents.

*The likelihood of injury is extremely high in these motorcycle accidents; 98% of the multiple vehicle collisions and 96% of the single vehicle accidents resulted in some kind of injury to the motorcycle rider; 45% resulted in more than a minor injury.

*Half of the injuries to the somatic regions were to the ankle-foot, lower leg, knee, and thigh-upper leg.

*Crash bars are not an effective injury countermeasure; the reduction of injury to the ankle-foot is balanced by increase of injury to the thigh-upper leg, knee, and lower leg.

*The use of heavy boots, jacket, gloves, etc., is effective in preventing or reducing abrasions and lacerations, which are frequent but rarely severe injuries.

*Groin injuries were sustained by the motorcyclist in at least 13% of the accidents, and typified by multiple vehicle collision in frontal impact at higher than average speed.

*Injury severity increases with speed, alcohol involvement and motorcycle size.

*Seventy-three percent of the accident-involved motorcycle riders used no eye protection, and it is likely that the wind on the unprotected eyes contributed an impairment of vision which delayed hazard detection.

*Approximately 50% of the motorcycle riders in traffic were using safety helmets but only 40% of the accident-involved motorcycle riders were wearing helmets at the time of the accident.

*Voluntary safety helmet use by those accident-involved motorcycle riders was lowest for untrained, uneducated, young motorcycle riders on hot days and short trips.

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*Voluntary safety helmet use by those accident-involved motorcycle riders was lowest for untrained, uneducated, young motorcycle riders on hot days and short trips.

*The most deadly injuries to the accident victims were injuries to the chest and head.

*The use of the safety helmet is the single critical factor in the prevention or reduction of head injury; the safety helmet which complies with FMVSS 218 is a significantly effective injury countermeasure.

*Safety helmet use caused no attenuation of critical traffic sounds, no limitation of pre-crash visual field, and no fatigue or loss of attention; no element of accident causation was related to helmet use.

*FMVSS 218 provides a high level of protection in traffic accidents, and needs modification only to increase coverage at the back of the head and demonstrate impact protection of the front of full facial coverage helmets, and insure all adult sizes for traffic use are covered by the standard.

*Helmeted riders and passengers showed significantly lower head and neck injury for all types of injury, at all levels of injury severity.

*The increased coverage of the full facial coverage helmet increases protection, and significantly reduces face injuries.

*There is no liability for neck injury by wearing a safety helmet; helmeted riders had less neck injuries than unhelmeted riders. Only four minor injuries were attributable to helmet use, and in each case the helmet prevented possible critical or fatal head injury.

*Sixty percent of the motorcyclists were not wearing safety helmets at the time of the accident. Of this group, 26% said they did not wear helmets because they were uncomfortable and inconvenient, and 53% simply had no expectation of accident involvement.

*Valid motorcycle exposure data can be obtained only from collection at the traffic site. Motor vehicle or driver license data presents information which is completely unrelated to actual use.

*Less than 10% of the motorcycle riders involved in these accidents had insurance of any kind to provide medical care or replace property.

12.2 Recommendations and Proposed Countermeasures

Training

Specialized motorcycle rider training courses were not readily available during the times of accident or exposure data collection. Consequently there were not many riders who had the advantage of such specialized motorcycle rider training, and the majority of the riders interviewed were untrained and had learned whatever they knew about motorcycles from their own experience or from family and friends. This lack of training was a significant factor in accident involvement and it is clear that motorcycle riders benefit greatly from such specialized training and could develop important skills, strategies and attitudes to limit accident involvement and reduce injury severity.

The Motorcycle Rider Course of the Motorcycle Safety Foundation should be the prerequisite (or at least corequisite) of licensing and use of a motorcycle in traffic. This course is well developed and has proven effective by

containing the basic ingredients for safe operation of motorcycles in traffic. An additional focus of the MSF Motorcycle Rider Course should be to incorporate the critical areas of knowledge on safe traffic strategy and collision avoidance skills which were shown to be especially critical by this research.

If the training is not associated with some aspect of licensing or traffic enforcement, other avenues of safety education will face great difficulty because the target group of laborers, students and unemployed will be an abstract and mobile body with limited prospects of effective communication.

Research is needed to develop effective training methods for collision avoidance braking skills on contemporary motorcycles, and also to investigate the benefits of interconnected brake systems, e.g. Moto Guzzi T-3, and anti-lock or antiskid brake systems, e.g. TRRL Lucas-Girling Norton 850.

Licensing

The accident-involved motorcycle riders are shown to be significantly without license, or any special motorcycle license endorsement. This is a reliable indication that these riders do not have the the necessary skills and traffic strategies to operate safely in traffic, especially when so many of those accidents will be caused by another driver. All motorcycle riders in traffic should have the basic license plus a special endorsement or supplementary license for motorcycle operation.

The special license for motorcycle operation should require special examinations of substance and authority, so that emphasis and attention to safe operation of the motorcycle is given a true priority. Some brief "Simon says" type of written examination and casual riding examination by an unqualified remote observer serve no effective purpose and demean the object of licensing. The written and traffic rider examinations should be realistic and authoritative.

The demonstration programs conducted by NHTSA Traffic Safety Programs in San Diego and Sacramento, California, have shown an appropriate and effective level of attention to this problem and should be instituted as a basic requirement as soon as possible. A detailed examination with authority and substance is necessary to provide the proper emphasis and attention to the critical accident involvement of the unlicensed motorcycle riders.

Law Enforcement

Law enforcement has a special contribution to make in the prevention of motorcycle accidents. Some of these contributions are simple and some are very difficult: dirt bikes in traffic are an obvious hazard; motorcycle riders without license are not easy to detect or stop without cause, and alcohol-involved motorcycle riders are far more difficult to detect than alcohol-involved automobile drivers. The excess involvement of the unlicensed rider in all accidents, and the alcohol-involved rider in fatal accidents, demands enforcement action, but legal requirements of due cause for a traffic stop may limit this action. The data of this research should provide the basis of "due cause" for preliminary enforcement action and screening of traffic for unlicensed riders.

One fundamental communication system is available through the motorcycle rider under citation for traffic violation. The data of this research show that driver improvement is vital to those motorcycle riders who have had traffic violations or accidents, and experience has shown that a special motorcycle "traffic school" is an effective alternative to the payment of fine for citation. Advantage should be made of this contact opportunity to require a special motorcycle traffic school for motorcycle riders with traffic citations so that critical information can be given to these likely accident candidates.

One impression developed during this research, and encountered in many motorcycle accident investigations throughout the various states, was the lack of punitive action for the culpable driver of the other vehicle involved in the accident with the motorcycle. The outward appearance is that the offending driver is rarely faced with effective prosecution of right-of-way violation, negligent or reckless driving causing injury, or even vehicular manslaughter. Often there is the incorrect impression of excess speed or recklessness of the motorcycle rider. In most cases there is not an adequate collection of evidence and accurate reconstruction of the accident because of the police traffic accident investigator's unfamiliarity with motorcycle accident analysis. Many times there is simply the impression that "this was just another motorcycle accident." This lack of effective punitive action needs research for a more precise definition of the problem and evaluation for accident countermeasures.

Protective Equipment

This research shows that there is a critical need for the use of protective equipment by every motorcycle rider. The contemporary motorcycle safety helmet provides a spectacular reduction of head AND neck injury, without any adverse effect on vision or hearing, or vulnerability for other injury. This research shows NO reason for any motorcyclist to be without a safety helmet.

Eye protection is vital to preserve vision as well as protect the eyes and face. The failure to wear eye protection appears as an unreasonably frequent factor for the accident-involved rider, and the use of contemporary eye protection involves only benefit and no hazard. Of course, the safety helmet is the most convenient foundation for eye protection such as a face shield.

The traditional heavy jacket, gloves, pants and boots are clearly effective in reducing the most common abrasions, i.e. "road rash." An important improvement would be to insure that the upper torso garment be an effective contribution to conspcuity.

Conspicuity

The driver of the other vehicle involved in collision with the motorcycle DID NOT SEE the motorcycle, or did not see the motorcycle until it was too late to avoid the collision. In some instances, it was clear that there was some view obstruction or limitation of vision for the other vehicle of the motorcycle (usually stationary or mobile vehicles), and this points out the

need for the motorcycle rider to develop a traffic strategy so that he can SEE AND BE SEEN in traffic. This should be the most important component of any motorcycle rider training program.

However, the most frequent case was truly that of the other vehicle driver failing to detect the motorcycle in traffic. In such cases it was clear that the increased conspicuity would reduce accident involvement. The data from this research are conclusive in the favorable factors to increase conspicuity: headlamp on in daytime is highly effective, bright upper torso garments are very helpful, while war surplus army jackets are deadly, and fairings and windshields apparently make the small silhouette of the motorcycle larger and more conspicuous.

The conspicuity problem is a complex one and in greatest part it is a problem of the frontal surfaces of the motorcycle. The simple countermeasures listed above are surely effective, but more fundamental scientific research may uncover additional effective treatments based upon human factors, e.g. the "Q-switch" based on the Bartley effect, Vetter "Leading Edge Lights" to increase contrast conspicuity in the frontal regions, etc.

Federal Motor Vehicle Safety Standards

Federal Motor Vehicle Safety Standard 218 governing motorcycle safety helmets provides a high level of protection for the typical traffic accident, and appears to need only minor modifications. The coverage for impact attenuation should be extended to include the lower back of the head, and full facial coverage helmets should demonstrate some sort of impact attenuation by the chin piece. Helmet conditioning prior to test could be more realistic, and retention system test should include some component of side force.

The data of this accident research do not indicate the need for more severe requirements of impact, penetration and retention performance. In fact, it is recommended that the present minimum performance standards be maintained because more severe standards would have an undesirable and adverse effect on the minimum cost of a qualified helmet.

All adult sizes of safety helmets should be covered by this standard so that all motorcycle riders will have the assurance of a qualified helmet for protection. The application of the standard in past time to "medium size" only has created considerable questions among consumers and decreased the public confidence in the standard.

Federal Motor Vehicle Safety Standard 119 governing new pneumatic tires appears to provide adequate guarantees of safe equipment. The few accidents due to puncture flats were not defect related and there were no standard-related problems of tires and wheels. The future increasing applications of tubeless tires which resist sudden deflation punctures will reduce this small area of accident causation.

Federal Motor Vehicle Safety Standard 122 establishes equipment and performance requirements for motorcycle brake systems. There were no standard-related problems discovered in these accident investigations; the very few brake mechanical problems were entirely related to defective or deficient

maintenance. On the other hand, these accident cases showed significant rider problems of effective braking for collision avoidance. Research is needed to investigate the potential improvement in collision avoidance performance by the use of interconnected and antilock or antiskid brake systems. Effective collision avoidance braking was a significant deficiency in these accident data with the typical accident-involved motorcycle rider skidding the rear tire but not using the front brake. It is possible that specialized rider training can not be an adequate countermeasure to improve collision avoidance braking, and the first objective should be to investigate the benefits of a well-designed interconnected front and rear brake system.

Federal Motor Vehicle Safety Standard 123 specifies the requirements for motorcycle controls and displays, stands, and footrests. The majority of the motorcycles examined in this research conformed to the standard, even though manufactured before the effective date of the standard. In a few instances, the validity of the standard was confirmed, e.g. a non-conforming, pre-standard motorcycle gave supporting evidence, with the rider precrash action of front hand brake use but downshifting with the right foot rather than left foot rear braking. The limited cases of a sidestand not retracted and grounding out involved pre-standard or modified motorcycles, and standard compliance would have prevented the associated loss of control.

There is a significant post-crash fire hazard at most motorcycle accidents, due to fuel spills and leaks. In greatest part, this is due to the post-crash posture of the motorcycle lying down on its side, far from the normal containment orientation of the fuel system. While it is expected that some fuel loss may occur in such post-crash posture, future improvements should focus on reducing this hazard. The tank cap must not protrude to cause groin injury or allow opening by the events of the typical crash impact, the carburetors should not continue to receive fuel from the tank to spill or leak, and the tank structure and fuel lines should demonstrate some minimum resistance to violation or damage in typical crash impacts. In contemporary time the fuel system configuration of the Honda Gold Wing demonstrates most of these features desirable for crashworthiness.

The accident research showed no contributions to accident causation from cable controls, wheels and rims, lack of side reflectors, or rear view mirrors.

13.0 REFERENCES

The following references were those used primarily by the research team. Of course, additional publications may be related to the subjects of the research, and used by individual team members as reference.

American Association for Automotive Medicine, Committee on Injury Scaling, The Abbreviated Injury Scale, 1976 Revision, American Association for Automotive Medicine, Morton Grove, Illinois, 1976.

Bothwell, P. W., Motorcycle Crash Tests, in Quest for Safety, (Ball, A., Ed.), the Jim Clark Foundation, London, 1975.

Bothwell, P. W., Knight, R. E., Peterson, H. C., Dynamics of Motorcycle Impact 1971-1973, Summary Report - Results of Crash Test Program and Computer Simulation, Final Report No. DRI-2621, 1973, (NTIS No. PB 226592).

Buchanan, L. S., Bischoff, D. C., Richardson, H. A., A Preliminary Analysis of Safety Helmet Effectiveness, Proceedings of the Second International Congress on Automotive Safety, 1973, SAE Paper No. 73013.

California Department of Motor Vehicles, Budget Section, Forecasting Unit, Estimated Fee Paid - Registration by County, California Department of Motor Vehicles, Sacramento, 1976, 1977, 1978, 1979.

California Department of Motor Vehicles, Electronic Data Processing Unit, Driver License Information Report, California Department of Motor Vehicles, Sacramento, 1977, 1978, 1979.

Fell, J. C., A Motor Vehicle Accident Causal System: The Human Element, NHTSA TR DOT-HS-801-214, July, 1974.

Hurt, H. H., Jr., Accident Investigation Methodology Peculiar to Motorcycles and Minibikes, Proceedings of the Second International Congress on Automotive Safety, 1973, SAE Paper No. 73051.

Hurt, H. H., Jr., Motorcycle Handling and Collision Avoidance: Anatomy of a Turn, Proceedings of the Second International Congress on Automotive Safety, 1973, SAE Paper No. 73032.

Hurt, H. H., Jr., & Dupont, C. J., Human Factors in Motorcycle Accidents, 1977, SAE Paper No. 770103.

Hurt, H. H., Jr., Ouellet, J. V., & Wagar, I. J., Analysis of Accident-Involved Motorcycle Safety Helmets, Proceedings of the Twentieth Conference of the American Association for Automotive Medicine, 1976.

Janoff, M. S., Motorcycle Noticeability and Safety During the Daytime, Proceedings of the Second International Congress on Automotive Safety, 1973, SAE Paper No. 73034.

Johnson, D. H., & Newman, J. A., Injury Mechanisms in Motorcycle Accidents, Scientific Conference on Traffic Safety, National Department of Health and Welfare, Ministry of Transport, Canada, 1974.

Marsh, J. M., An Occupant Injury Classification Procedure Incorporating the Abbreviated Injury Scale, Proceedings of the International Accident Investigation Workshop, 1973.

Newman, J. A. & Webster, G. D., The Mechanics of Motorcycle Accidents, Proceedings of the Eighteenth Conference of the American Association for Automotive Medicine, 1974.

Ouellet, J. V., Helmets, in Automobile Accident Reconstruction, (Barzelay, M., Ed.), Mathew Bender Publishing Co., N.Y., 1979.

Ouellet, J. V., Motorcycles, in Automobile Accident Reconstruction, (Barzelay, M., Ed.), Mathew Bender Publishing Co., N.Y., 1979.

Reiss, M. L., Berger, W. G. & Valette, G. R., Analysis of Motorcycle Accident Reports and Statistics, Biotechnology Inc., 1974.

Severy, D. M., Brink, H. M. & Blaisdell, D. M., Motorcycle Collision Experiments, Proceedings of the Fourteenth Stapp Car Crash Conference, 1970, SAE Paper No. 700897.

Weir, D. H., Motorcycle Handling Dynamics and Rider Control and the Effect of Design Configuration on Response and Performance, Ph.D. Dissertation, University of California at Los Angeles, 1972.

Weir, D. H., A Manual Control View of Motorcycle Handling, Proceedings of the Second International Conference on Automotive Safety, 1973, SAE Paper No. 73018.

Also, publications which were reports of progress on this research are as follows:

Hurt, H. H., Jr., Phase I Report - Motorcycle Accident Cause Factors and Identification of Countermeasures, U. S. Department of Transportation, 1976.

Hurt, H. H., Jr., Status Report of Accident Investigation Data, Motorcycle Accident Cause Factors and Identification of Countermeasures, DOT-HS-804-096, PB245682, 1979.